



Thermal Analysis and Battery Life of Lithium-Ion 60 Volt / 23 Ah with Variation of Engine Rate on 3000 W Electric Motorcycle Prototype

Arif Devi Dwipayana^{1*}, Ainul Ghurri², Suprpta Winaya³
^{1,2,3} Mechanical Engineering Udayana University, Indonesia

 arifdevidwipayana2212@gmail.com*

Abstract

Lithium-ion batteries in electric vehicles face challenges in terms of energy conversion efficiency and thermal resistance. One of the main factors affecting battery performance is the variation in engine speed, which has an impact on current consumption, voltage changes, and an increase in battery temperature. This study aims to comprehensively analyze the effect of engine speed variation on the electric current consumption, battery life, and thermal characteristics of a 60V/23Ah lithium-ion battery in a 3000W electric motorcycle prototype. In addition, this research also evaluates the durability of the battery under varying operational conditions to identify potential optimizations of the battery management system. The methods used in this research involved MATLAB-based experiments and simulations. Tests were conducted by measuring battery current, voltage, and temperature at six different engine speed levels, and then compared with simulation results developed using a mathematical model based on motor efficiency and battery internal resistance. The results show that an increase in engine speed is directly proportional to the current consumption and a decrease in battery voltage. In addition, the battery temperature increases steadily, with relatively small differences between experimental and simulation results. This research contributes to a better understanding of the energy dynamics of electric vehicle battery systems and offers a simulation model approach to optimizing the design of battery management systems. The results of this study can be used to improve energy conversion efficiency and extend battery life in electric vehicles. Further research can be conducted by considering more complex environmental parameters, such as cooling effects and vehicle dynamic load variations.

Keywords: Battery life, Electric current, Electric motor, Lithium-ion battery, Thermal

ARTICLE INFO

Article history:

Received

April 02, 2025

Revised

May 16, 2025

Accepted

June 29, 2025

Published by
ISSN

CV. Creative Tugu Pena
2963-6752

Website

<https://attractivejournal.com/index.php/ajse>

This is an open access article under the CC BY SA license

<https://creativecommons.org/licenses/by-sa/4.0/>



INTRODUCTION

The global development of electric vehicles (EVs) continues to accelerate due to increasing concerns regarding energy sustainability, carbon emission reduction, and environmental protection. One of the most critical components in EV technology is the lithium-ion battery, whose performance, safety, and degradation behavior directly influence vehicle reliability and operational efficiency. Globally, researchers have

highlighted significant challenges related to the thermal sensitivity of lithium-ion batteries, rapid degradation under high-load cycling, and the need for robust thermal management systems to prevent overheating and improve energy efficiency [8], [18], [19]. These challenges become more pronounced in regions with high ambient temperatures, where battery temperature rise can lead to accelerated capacity fade and reduced cycle life. In the Indonesian context, the rapid growth of electric motorcycles—driven by government policies and market penetration—demands deeper investigation into battery performance under real operational conditions. Indonesia’s tropical climate, with consistently high ambient temperatures, presents unique challenges for lithium-ion battery stability, thermal performance, and safety. Despite increasing EV adoption, studies focusing on the dynamic behavior of lithium-ion batteries under varying motor speeds and local thermal conditions remain limited. As such, the Indonesian EV landscape presents a relevant case study to examine battery behavior under high-temperature environments and fluctuating mechanical loads. Electric vehicles require batteries as the primary power source for driving various electrical components, such as the starter motor, lighting (lamps), horn, and others [1]. Given the critical role of batteries in achieving energy transition, battery modelling and degradation have been extensively studied to characterize their physical, thermal, and chemical properties [2], [3], especially for electric vehicle applications [4]. Batteries are essential for supplying energy to all electrical components in electric vehicles, making them a vital power source for these systems [5]. Batteries generate electricity through chemical processes [6]. There are two main types of batteries based on their chemical processes: 1) Primary batteries are batteries consisting of a single cell or a collection of cells that generate electrical energy for single-use applications and are then discarded after depletion. These batteries are assembled in a charged state, with discharge being the primary process during their operation. 2) Secondary batteries consist of a single cell or a group of cells that can generate electrical energy and can be recharged to their original charged state after being depleted, by reversing the current flow. This type of battery is also referred to as a rechargeable battery. Since secondary batteries are usually assembled in a discharged state, they must be charged before initial use [7]. Battery performance degrades over time due to various internal and external factors. For lithium-ion batteries used in electric vehicle applications under different operating conditions, this becomes a major concern [8]. The internal and external issues and challenges are classified into several categories, as illustrated in Figure 1:

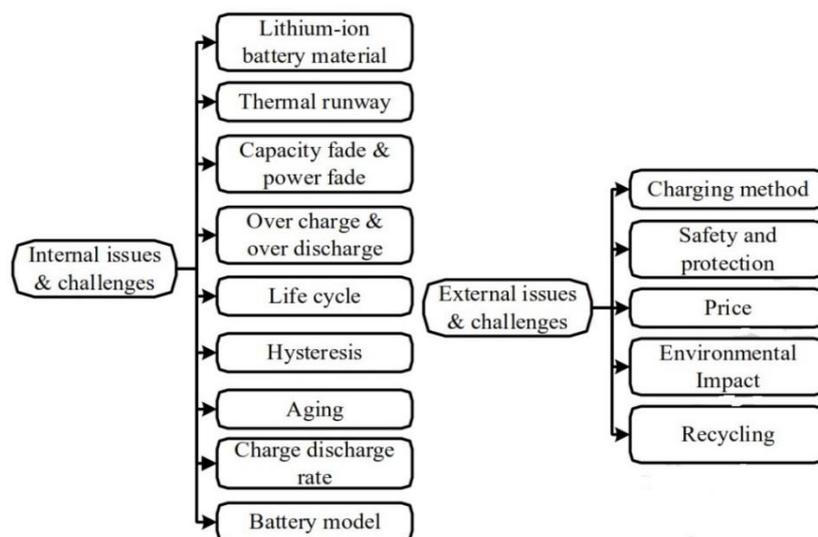


Fig 1. Classification of electric battery problems and challenges [2]

There are theoretical and empirical approaches in battery modelling to determine battery life. In theoretical models, the chemical properties of materials and fusion dynamics are accurately described to obtain numerical or mathematical models [9]. These models are usually highly complex as they require a large number of parameters related to materials, construction processes, and geometries, which are often unknown and difficult to estimate [10]. Moreover, physical and chemical theories involve equations that are complex to handle. The empirical approach tends to be simpler but requires the implementation of several tests over a period of months to accurately capture the battery's degradation dynamics in terms of stress type [11], [12], temperature, current, operating cycles, and time-period [13]. Battery aging can be described as a superimposition of different degradation factors such as time, temperature, and power operation, which are categorized into two main groups [14], [15]: calendar life, which refers to battery aging effects related to service time, and cycle life, which relates to operating conditions of battery cycling. Temperature conditions significantly influence the rate of battery degradation. Power in batteries plays a key role in the development of electric vehicles [16]. This is because, to create electric vehicles with high efficiency, batteries with high specific power density and specific energy density are required. Various types of batteries such as lead-acid, zinc/halogen, metal/air, sodium-beta, nickel metal hydride (NiMH), and lithium-ion (Li-ion) can be used to supply power to electric vehicles [17]. However, among these battery types, Li-ion has proven to be the most promising for use as an energy storage system in electric vehicles due to its high energy density, lighter weight, absence of memory effect, lower self-discharge rate compared to other secondary batteries, long driving range, and fast acceleration capability [18], [19].

These advantages have led previous research on Li-ion batteries to primarily focus on the development of battery materials aimed at improving specific energy, power, and cycle life, rather than on issues related to efficiency and thermal performance. One significant thermal-related issue of Li-ion batteries is their high sensitivity to temperature [20]. This poses a critical problem since the operating temperature of Li-ion batteries is closely linked to battery performance, lifespan, and safety. During the charging and discharging processes, battery temperature increases due to the heat generated by electrochemical reactions [21]. Generally, the operational temperature range for Li-ion batteries is between 250–400°C; however, excessive temperature rise can lead to overheating and the risk of explosion [22]. This makes thermal management systems essential to address the thermal issues associated with Li-ion batteries. Ikhwan [23] conducted a study on the analysis of output power from a battery charging system in a hybrid motorcycle, using variations in the rotational speed of the electric motor drive wheel based on an Arduino system. The sampling technique involved testing the hybrid motorcycle at different motor drive wheel speeds: 400 rpm, 500 rpm, and 600 rpm. The results showed that the fastest battery charging time was 55.8 minutes at 600 rpm, and the highest output power was also obtained at 600 rpm, reaching 665.27 Watts. Afzal et al. [24] conducted research on thermal modeling and evaluation of the characteristics of electric vehicle battery systems.

The findings revealed that the thermal behavior of Li-ion battery cells in modern electric vehicles depends on operational parameters, and under certain conditions, the temperature distribution during charging and discharging can exceed the allowable limits. This situation can lead to critical temperatures within the battery cells, resulting in thermal runaway. Several existing studies have examined lithium-ion thermal behavior and battery degradation models; however, most research either relies exclusively on simulations or focuses on stationary laboratory cycling. There remains a research gap in combining experimental measurements and MATLAB-Simulink simulation specifically for 60V/23Ah lithium-ion batteries used in electric motorcycles with RPM-based load variation. Current literature has not sufficiently compared simulation-based thermal models with real-world dynamometer data, particularly regarding battery current

consumption, voltage drop characteristics, and temperature rise under variable speed conditions. Based on this gap, the present study aims to bridge the disparity between theoretical modeling and experimental practice by analyzing the effect of motor RPM variations on battery current, thermal behavior, and battery life. The study integrates experimental measurements and MATLAB-based modeling to evaluate performance under realistic operational conditions.

The objectives of this research are: 1) to analyse the effect of variations in motor speed on the battery's electric current consumption in an electric motorcycle, 2) to analyse the effect of variations in motor speed on the thermal behaviour of the battery in an electric motorcycle, 3) to analyse the effect of variations in motor speed on the battery life of an electric motorcycle. Based on the findings from the studies and literature, the focus of the current research will be to compare the thermal behaviour and battery life of Li-ion batteries through both experimental and simulation approaches.

Lithium-ion battery

The lithium-ion battery was first publicly introduced in 1990 by Dr. John Goodenough from the University of Texas [25]. Lithium-ion batteries became the most demanded type in manufacturing, reaching 660 million cylindrical cells and 700 million pouch-type batteries [26]. Lithium-ion batteries are the most widely chosen type for electronic devices due to their higher energy density compared to other batteries on the market. Figure 2 illustrates that lithium-ion batteries operate similarly to other battery types, where the charging process begins with lithium ions moving from the cathode to the anode through the electrolyte as a medium. The discharging process is characterized by the movement of lithium ions through the electrolyte from the anode back to the cathode.

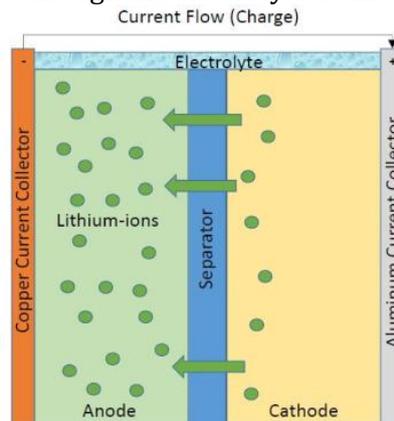


Fig 2. Lithium ion flow in battery cells [27]

Hossain et al. [2] conducted a study titled "A Review of State of Health and Remaining Useful Life Estimation Methods for Lithium-Ion Batteries in Electric Vehicles: Challenges and Recommendations." The aim of the study was to provide a comprehensive literature analysis on various approaches to estimate the State of Health (SOH) and Remaining Useful Life (RUL) of lithium-ion batteries. SOH and RUL were evaluated using several common methods, including traditional techniques, model-based approaches, and algorithm-based models. Traditional estimation methods have low power consumption and are easy to implement, but they are highly susceptible to aging, temperature, and external disturbances. Model-based estimation methods require less computational cost and offer high time efficiency; however, they often suffer from poor robustness due to model uncertainties. Aging, temperature variations, and noise can be addressed using algorithm-based methods, although these methods tend to involve complex computations and require large amounts of data for accurate research outcomes. This study uses a 60-Volt 23 Ah lithium-ion battery with the following specifications:

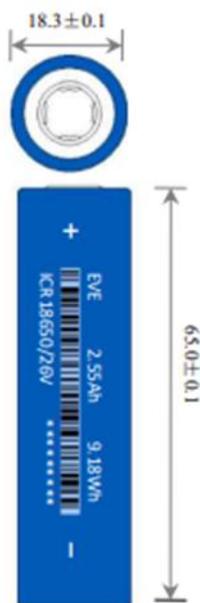
Table 1. 60-Volt 23 ah lithium-ion battery specifications

Min Capacity ⁽¹⁾	2500mAh
Type Capacity ⁽²⁾	2550mAh
Nominal Voltage	3.6 V
Impedance	25 ± 3mΩ
Charging	CC-CV, Std. 1275mA 4.20V, 3hrs
Weight (avg)	45.0 ± 1.0g
Temperature	Charge: 0 to + 45°C Discharge: -20 to + 60°C Storage: -20 to + 45°C
Energy Density ⁽³⁾	Volumetric: 530 Wh/L Gravimetric: 200 Wh/Kg

- (1) At 250C, 4.2V to 2.5V using 0.2C discharge current
- (2) At 250C, 4.2V to 2.5V using 0.2C discharge current
- (3) Energy density based on max. cell dimensions or max. weight.

Dimensions

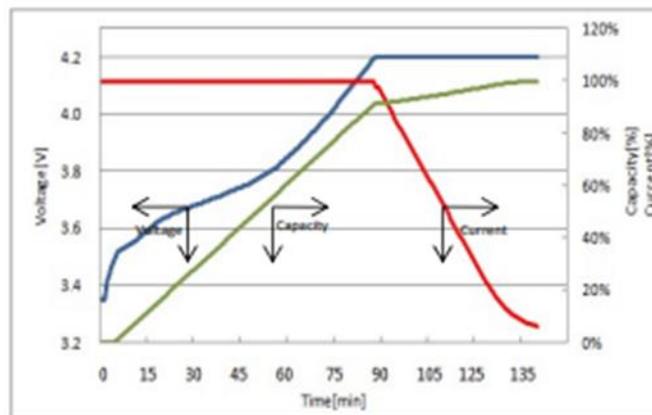
Unit: mm



(a)

Charge Characteristics

Charge : CC-CV 0.5C mA, 4.20V, 0.02C mA cut-off at 25°C



(b)

Fig 3. (a) Battery unit dimensions, (b) charge characteristic chart

The graph in Figure 3 (b) shows that the blue line represents the battery charging process starting from 3.4 Volts, which takes 90 minutes to reach 100% capacity. The green line illustrates the charging process from 0 Volts to 100% capacity, which requires 135 minutes. The red line indicates battery usage starting from 100% capacity, which lasts for 90 minutes before the capacity decreases to 0%.

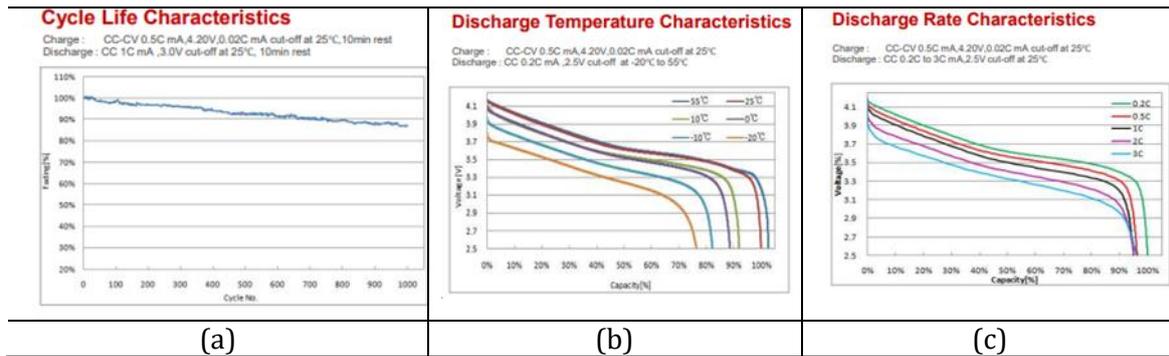


Fig 4. (a) Cycle life characteristics, (b) discharge temperature characteristics, (c) discharge rate characteristics

The graph in Figure 4 (a) shows the battery life cycle characteristics, where the battery undergoes capacity degradation over 1000 cycles (one cycle is from 0% to 100% capacity and from 100% to 0%). In (b), the orange line indicates that at a temperature of -20°C and a battery voltage of 3.7 Volts, the battery experiences a degradation of 75%, as do the other lines with different colours. In (c), the graph illustrates the battery discharge characteristics. The blue line represents a temperature of 30°C and a battery voltage of 3.9 Volts, where the discharge rate is 95%. Similarly, the other lines also represent different conditions

Thermal battery operating system

Thermal management of a battery can be simply described as the integration of various forms of heat exchangers installed within the battery system to regulate and maintain its temperature close to a constant level. There are various methods that can be used, but the most applied approach involves transferring heat from the battery cells to the outside through a specific medium [27]. The complexity of a battery thermal management system depends on three main factors. The first factor is the battery's duty cycle — the greater the power demand, the more heat will be generated by the battery cells. The second factor is the environment in which the battery operates. The third factor is the chemical reactions occurring within the battery, as different reactions will result in different operating temperatures.

Electric current in lithium-ion batteries

Electric current is the continuous and uninterrupted flow of electrons through a conductor caused by a difference in the number of electrons at various locations with unequal electron concentrations. In this study, the battery current is measured experimentally using an ammeter by varying the load and is also compared through simulation using MATLAB Simulink. A battery cell is a single electrochemical unit that can be connected in series or parallel depending on the requirements to form a module. Each module is equipped with its own battery management system (BMS), so the number of cells in a module depends on the BMS level of the module. Modules are then connected in series or parallel to form a battery pack. Finally, the battery pack is housed in a metal or plastic enclosure that contains the battery management system and the thermal management system of the pack. Battery pack design has undergone significant development in recent years, enabling the storage of more energy and increasing driving range while keeping the pack relatively compact [21], [28].

Lithium-ion battery life

The lifespan of electric vehicle batteries is significantly influenced by several factors related to vehicle usage, such as driving patterns, acceleration behaviour, charging habits, and even ambient temperature [20], [29]. In essence, battery life is affected by the battery's chemical properties and the duration spent at upper and lower temperature limits. All of these contribute to battery degradation through different mechanisms, which are reflected in the progressive decline of vehicle performance—most notably, the reduction in driving range due to the gradual decrease in battery capacity over time.

Figure 5 shows that cycle life decreases gradually at temperatures below 10°C due to anode plating. Conversely, there is a sharp decline in battery life when the temperature exceeds 60°C because of chemical damage. The ideal operating temperature range should not be too wide or too narrow, as lithium-ion batteries have a finite cycle life and should not be operated at excessively low or high temperatures. In this study, battery life is defined as the usable lifespan of the battery based on its capacity (State of Charge or SOC) when fully charged and then discharged to determine the amount of used capacity (Depth of Discharge or DOD) by applying variations in electric motor speed.

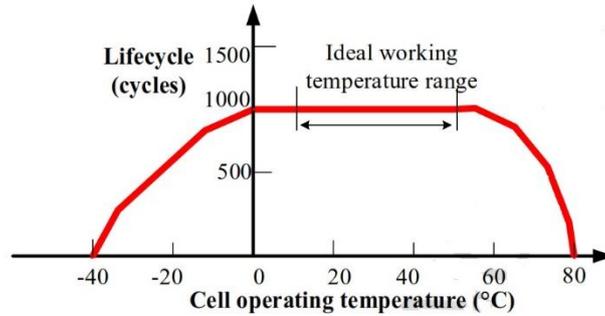


Fig 5. Figure Correlating battery cycle life with cell operating temperature

Electric motor rotation

Electric motors generate linear or rotational force (torque) intended to drive various external mechanisms, such as fans or elevators. Electric motors are typically designed for continuous rotation or for linear motion over a distance significant relative to their size. Electromagnetic solenoids can generate substantial mechanical force, but only over operating distances comparable to their size. Transducers such as speakers and microphones convert between electric current and mechanical force to reproduce signals like sound. Compared to conventional Internal Combustion Engines (ICE), electric motors are lighter, physically smaller, deliver higher power output, are mechanically simpler, and cheaper to manufacture. They also offer instant and consistent torque at any speed, better overall efficiency, and lower heat generation. In this study, a 3,000-Watt BLDC (Brushless DC) electric motor from QS brand is used. The motor speed is varied from 2,500 rpm to 5,000 rpm using a dynamometer (dynotest). Viantama and Suyitno [30] conducted a study titled "Performance System Comparison Analysis of Electric Drive Motors in a 75 kWh Electric Car." Their results showed that the induction motor for the electric vehicle produced a rotation speed of 1,500 rpm and power output of 375 kW, with a maximum torque of 582 N.m and a minimum of 271.2 N.m. The battery endurance reached 189.3 hours. Furthermore, the vehicle achieved an acceleration from 0 to 100 km/h in just 5 seconds.

Matlab simulink simulation

Modelling is utilized in various contexts, such as performance optimization systems, software development, research, and education. Today, simulations are widely used to obtain real-time results before conducting experimental procedures [24]. In this study, simulation was carried out using MATLAB Simulink to analyse the thermal behaviour and battery life of a 60 Volt 23 Ah lithium-ion battery, as well as the efficiency generated. Figure 6 illustrates the simulation model interface, while Figure 2.13 presents the battery configuration and control devices. Martyanov et al. [31], through their research on the development of control algorithms in MATLAB-Simulink, found that the proposed approach enhanced the efficiency of the design and development process of control systems for complex objects. Their computer modelling of a multifunctional battery charging device involved virtually testing control system parameters with various charging strategies and control algorithms. The simulation model is presented as follows.

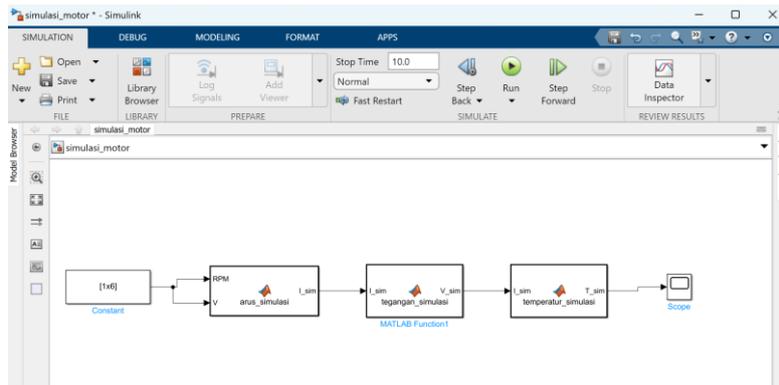


Fig 6. Simulation schematic

METHOD

This research design employs both experimental and simulation methods. The simulation method refers to the process of planning a model of a real-world system [32], followed by conducting experiments on the model to study system behaviour or evaluate strategies. Experimental research can be defined as a research method used to investigate the effect of a specific treatment under controlled conditions [33]. Experimental research involves conducting specially designed trials to generate the data required to answer the research questions.

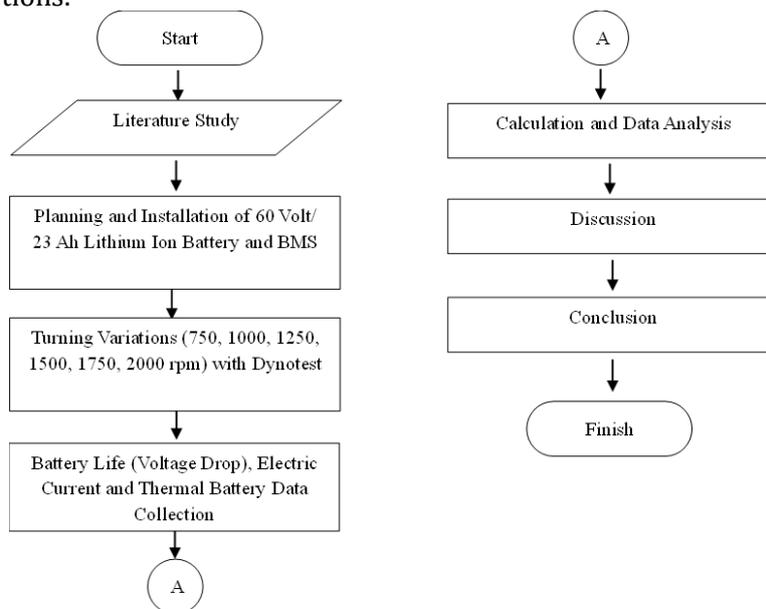


Fig 7. Experimental research procedure

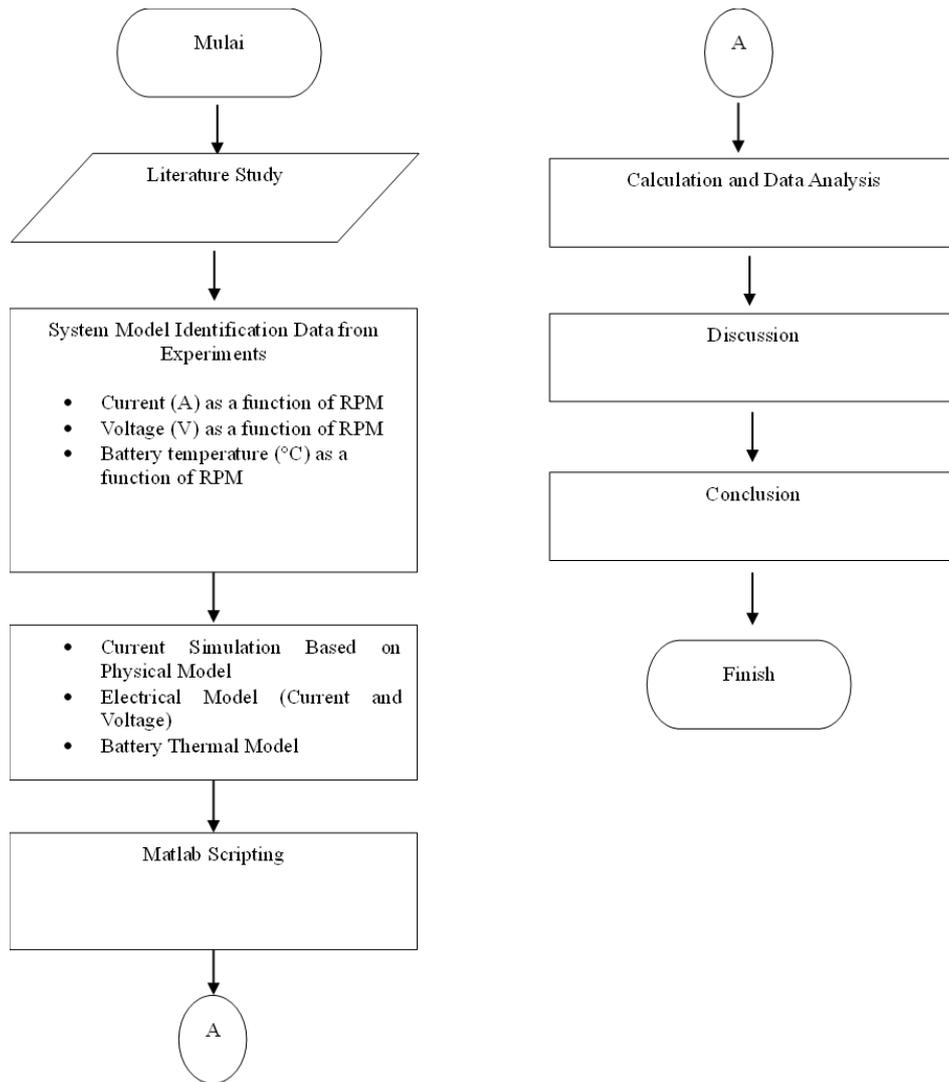
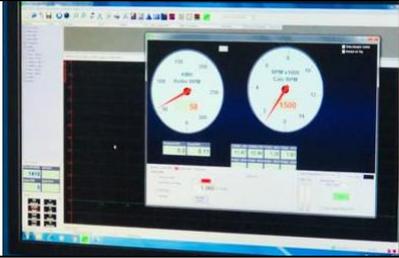


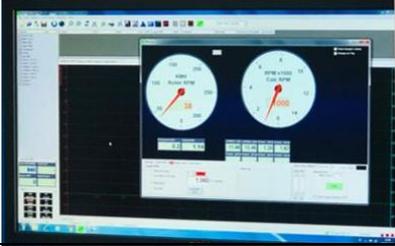
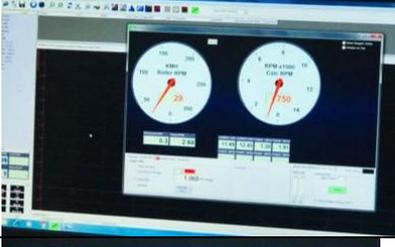
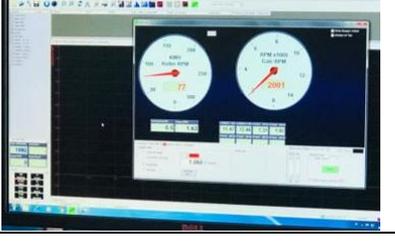
Fig 8. Simulation research procedure

RESULTS AND DISCUSSION

Current data collection on battery

Table 2. RPM and electric current data

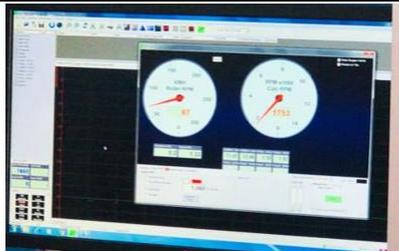
RPM	Electric Current	Description
		750 RPM
		1000 RPM

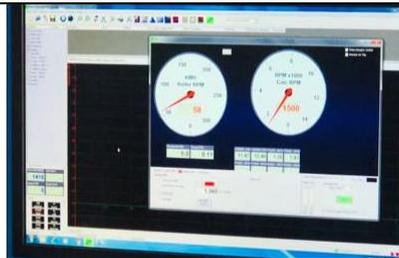
RPM	Electric Current	Description
		1250 RPM
		1500 RPM
		1750 RPM
		2000 RPM

From table shows the electric motor rotation of 750 rpm requires an electric current of 4.4 A, at 1000 rpm electric motor rotation requires an electric current of 5.2 A, at 1250 rpm electric motor rotation requires an electric current of 6.0 A, at 1500 rpm electric motor rotation requires an electric current of 6.8 A, at 1750 rpm electric motor rotation requires an electric current of 7.7 A and at 2000 rpm electric motor rotation requires an electric current of 8.1 A.

Voltage data collection on battery

Table 3. RPM and voltage data

RPM	Voltage	Description
		750 RPM

RPM	Voltage	Description
		1000 RPM
		1250 RPM
		1500 RPM
		1750 RPM
		2000 RPM

From table shows that the electric motor rotation of 750 rpm experienced a voltage drop of 66.9 Volts from 69 Volts with battery conditions not operated, at 1000 rpm the electric motor rotation experienced a voltage drop of 65.9 Volts, at 1250 rpm the electric motor rotation experienced a voltage drop of 65.4 Volts, at 1500 rpm the electric motor rotation experienced a voltage drop of 65.0 Volts, at 1750 rpm the electric motor rotation experienced a voltage drop of 64.6 Volts, and at 2000 rpm the electric motor rotation experienced a voltage drop of 63.7 Volts.

Battery thermal data capture

Table 4. Battery RPM and thermal data

RPM	Thermal Baterai (T_{max})	Description
-----	-------------------------------	-------------

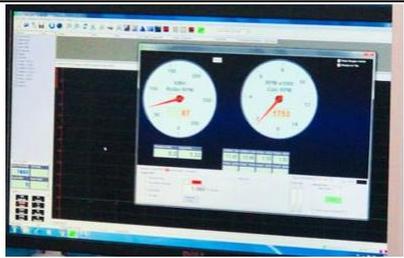
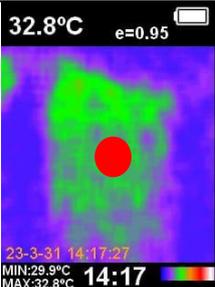
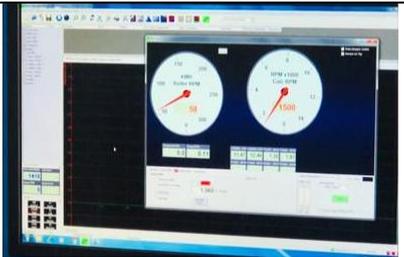
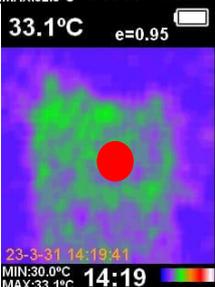
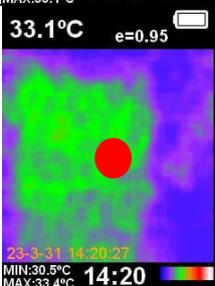
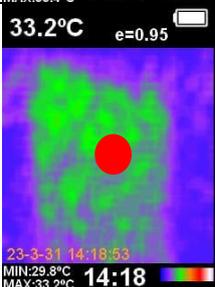
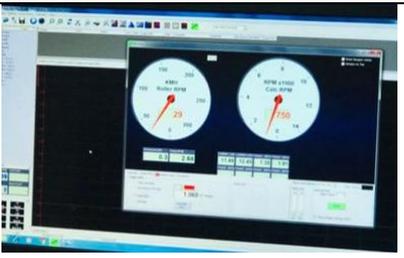
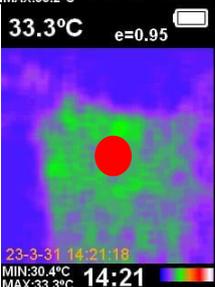
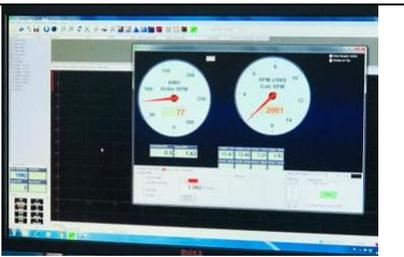
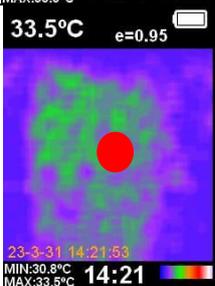
RPM	Thermal Baterai (T _{max})	Description
	<p>32.8°C e=0.95</p> 	750 RPM
	<p>33.1°C e=0.95</p> 	1000 RPM
	<p>33.1°C e=0.95</p> 	1250 RPM
	<p>33.2°C e=0.95</p> 	1500 RPM
	<p>33.3°C e=0.95</p> 	1750 RPM
	<p>33.5°C e=0.95</p> 	2000 RPM

Table shows that at 750 rpm the maximum temperature (T_{max}) on the battery is 32.8°C, at 1000 rpm the maximum temperature (T_{max}) on the battery is 33.1°C, at 1250 rpm the maximum temperature (T_{max}) on the battery is 33.1°C, at 1500 rpm the maximum temperature (T_{max}) on the battery is 33.2°C, at 1750 rpm the maximum temperature (T_{max}) on the battery is 33.3°C, and at 2000 rpm the maximum temperature (T_{max}) on the battery is 33.5°C.

Simulation using MATLAB

To create a simulation in MATLAB that can be compared with experimental data, a modeling of the electrical and thermal systems of the battery and electric motor was carried out. The steps taken are as follows:

System model identification

Based on experimental data, three main variables were identified: current (A) as a function of RPM, voltage (V) as a function of RPM, and battery temperature (°C) as a function of RPM.

Current simulation based on physical model

The electric current (I) as a function of RPM depends on several factors, such as the characteristics of the electric motor, efficiency, and applied load. To simulate the current (I) based on RPM, a model was developed to represent the relationship between RPM, motor torque, and battery power consumption. Relationship between current, torque, and RPM. For electric motors, the fundamental relationship is as follows:

$$P_{\text{motor}} = T \cdot \omega \quad (1)$$

Description:

P_{motor} = motor output power (watt)

T = motor torque (Nm)

ω = angular velocity, (rad/s), calculated by:

$$\omega = (2\pi \times \text{RPM}) / 60 \quad (2)$$

Power taken from the battery:

$$P_{\text{baterai}} = V \cdot I \quad (3)$$

Ignoring the loss, can estimate the flow as:

$$I = P_{\text{motor}} / V \quad (4)$$

In the RPM-based current simulation, the motor efficiency (η) is set at 85% and the motor torque as a function of RPM (fixed motor torque).

Electrical model (current and voltage)

The system can be modelled with a simple electrical circuit approach. The model is based on Ohm's law and battery characteristics:

$$V = V_{\text{OC}} - I R_{\text{(internal)}} \quad (1)$$

Description:

- V is battery voltage
- V_{OC} is battery open circuit voltage
- I is electric current
- R_{internal} is battery internal resistance

From the experimental data, we can determine the internal resistance of the battery using the equation:

$$R_{\text{internal}} = (V_{\text{OC}} - V) / I \quad (2)$$

Battery thermal model

The power generated by the battery can be calculated by:

$$P = V \times I \quad (3)$$

Some of this power turns into heat due to the internal resistance of the battery:

$$P_{\text{loss}} = I^2 R_{\text{internal}} \quad (4)$$

The temperature change of the battery can be calculated with the thermal heating model:

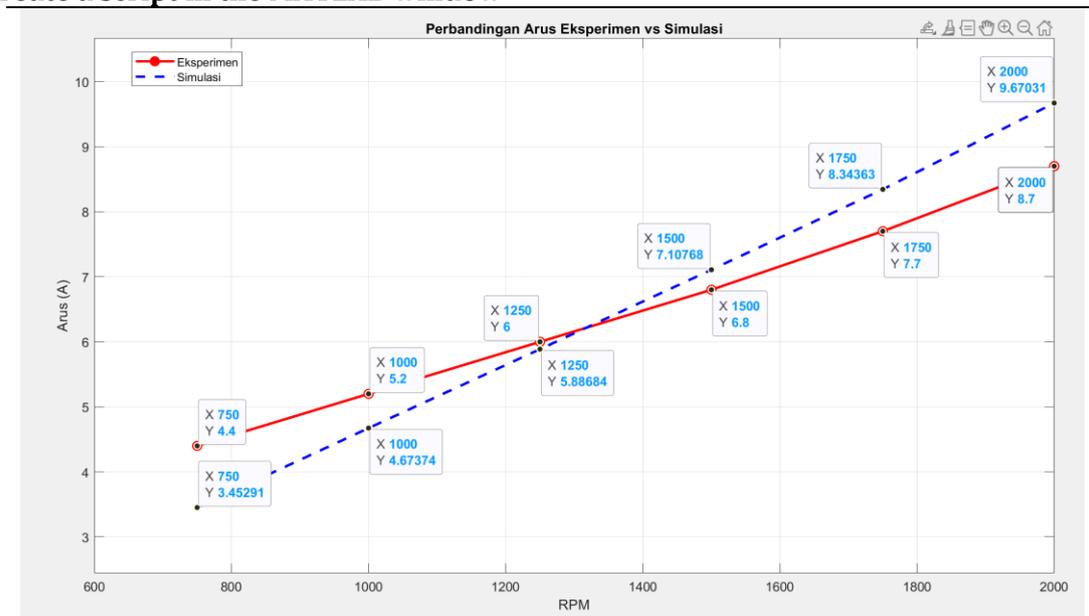
$$\Delta T = P_{\text{loss}} / m C_p \quad (5)$$

Description:

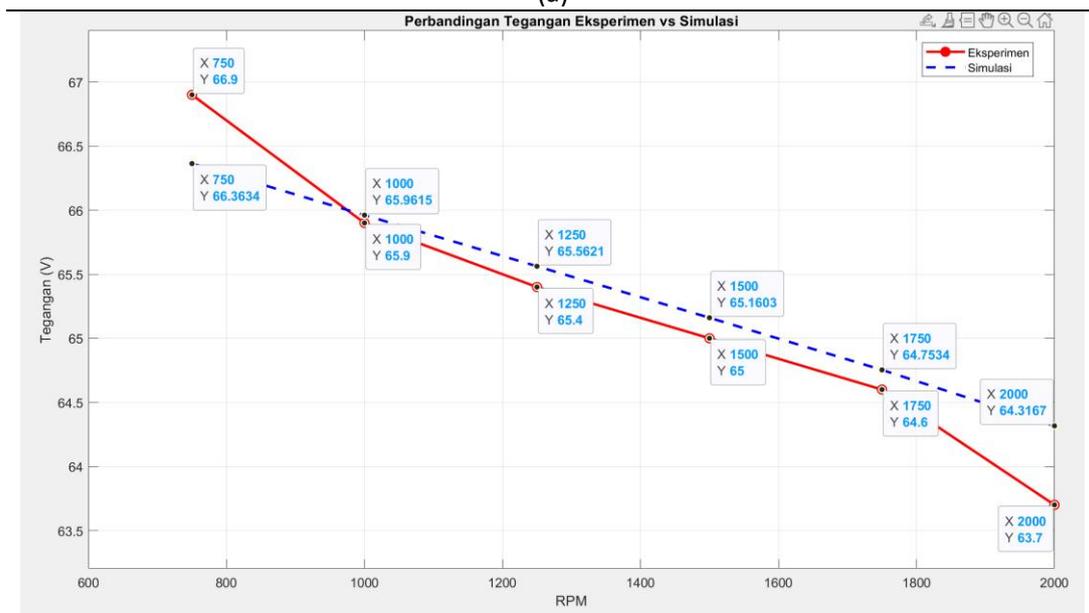
- m is the mass of the battery

- CP is the specific heat capacity of the battery

Create a script in the MATLAB window



(a)



(b)

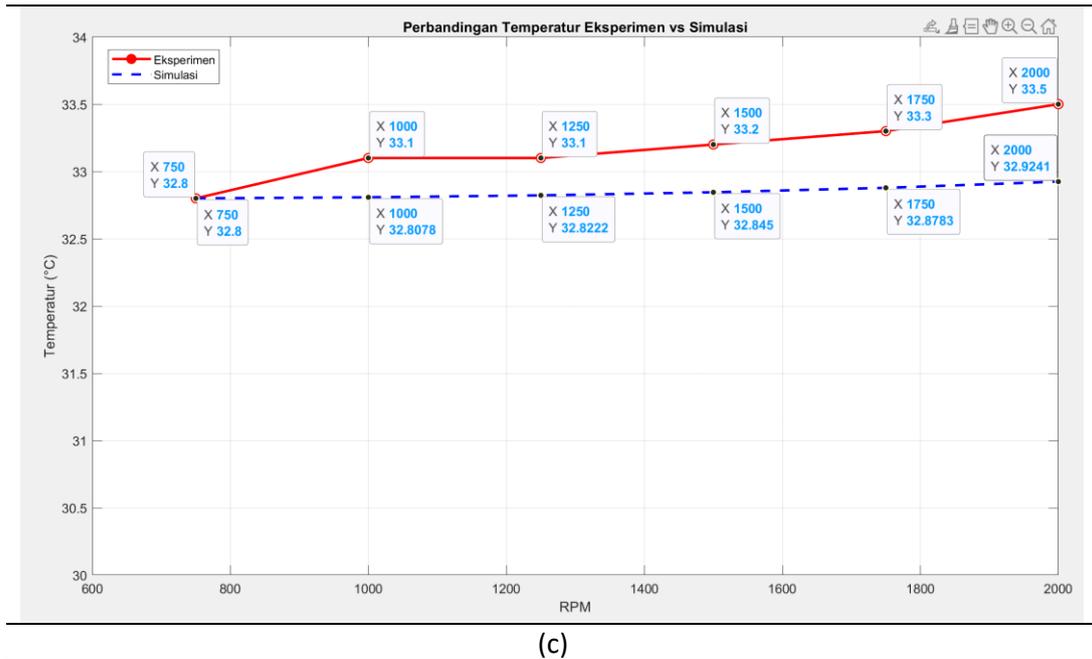


Fig 9. (a) Comparison of experimental and simulated current consumption, (b) comparison of experimental and simulated voltage (battery runtime), (c) comparison of experimental and simulated temperature.

DISCUSSION

(a) Electric motorbike rotation variation has an influence on battery current consumption.

Figure 9 (a) shows that as the motor RPM increases, the electrical current consumption also rises. At low RPM (750 RPM), the current consumed is relatively small, around 3.45 A – 4.4 A. As the RPM increases to 2000 RPM, the current rises to approximately 8.7 A – 9.67 A. This increase in current occurs because the power required by the motor increases, in accordance with the basic formula $P = V \times I$. The experimental current values are higher than those in the simulation, likely due to system losses such as cable resistance, inverter efficiency, and mechanical friction. Higher motor rotation results in greater current consumption, which directly impacts the battery load and energy efficiency. Overall, the simulation data demonstrates a reasonably good agreement with the experimental data, indicated by a similar trend and a relatively small deviation between the two. The increase in electrical current caused by high motor RPM leads to greater energy consumption during the discharging process (discharge rate), which consequently affects both the battery life or runtime, as well as the overall battery lifespan, since a shorter battery life necessitates more frequent charging cycles.

(b) Electric motorbike rotation variation has an influence on battery thermal temperature

Figure 9 (b) illustrates that the battery temperature increases with rising RPM. At 750 RPM, the initial battery temperature for both experimental and simulation conditions is approximately 32.8°C – 32.9°C. At 1000 RPM, the experimental temperature rises to 33.1°C, while the simulated temperature increases to 32.80°C (a difference of 0.2922°C or 0.88%). At 1250 RPM, the experimental temperature remains at 33.1°C, while the simulation shows a rise to 32.8222°C (a difference of 0.2778°C or 0.84%). At 1500 RPM, the experimental temperature increases to 33.2°C, while the simulation reaches 32.845°C (a difference of 0.3550°C or 1.07%). At 1750 RPM, the experimental temperature rises to 33.3°C, while the simulation shows 32.8763°C (a difference of 0.4237°C or 1.27%). At 2000 RPM, the experimental temperature increases to 33.5°C, while the simulated temperature reaches 32.9241°C (a difference of 0.5759°C or 1.72%).

This temperature increase is caused by the higher current at elevated RPMs, which leads to greater power dissipation due to the battery's internal resistance. The discrepancies between experimental and simulation results indicate the influence of environmental effects, such as ventilation or heat dissipation, which were not accounted for in the simulation. At high RPMs, internal heat generation within the battery increases due to rising current, which may lead to a reduction in battery lifespan if allowed to operate over extended periods without an effective cooling system. The increase in current due to high motor RPM eventually raises the battery's operating temperature, which also affects the chemical processes within the battery and influences its runtime. If the temperature remains within the ideal discharging range, this increase will not have a critical or damaging impact.

(c) Electric motorbike rotation variation has an influence on battery life

Figure 9 (c) shows that the battery voltage decreases as the RPM increases. At 750 RPM, the battery voltage is approximately 66.9 V (experimental) and 66.36 V (simulation). At 1000 RPM, the battery voltage in the experiment is 65.9 V, and in the simulation, it is 65.9615 V. At 1250 RPM, the experimental voltage is 65.4 V, while the simulated voltage is 65.5621 V. At 1500 RPM, the experimental voltage is 65 V, and the simulated value is 65.1603 V. At 1750 RPM, the experimental voltage is 64.6 V and the simulation shows 64.7534 V. When the RPM increases to 2000 RPM, the voltage drops to 63.7 V in the experiment and 64.3 V in the simulation.

This voltage drop is caused by the battery's internal resistance: the higher the current flow, the greater the voltage drop. Battery runtime becomes shorter at higher RPMs due to increased power consumption. The higher the RPM, the faster the battery voltage declines, indicating a quicker reduction in battery runtime under high load conditions.

DISCUSSION

The findings of this study reveal patterns that both align with and diverge from theoretical expectations presented in earlier research. The increase in current and temperature with higher motor RPM is consistent with the thermal sensitivity trends described by Afzal et al. [24] and Zhao et al. [19], where higher loads induce increased heat generation due to internal resistance and electrochemical activity. However, the relatively small temperature rise observed in this study (32.8–33.5°C) differs from the larger gradients predicted in several simulation-based studies, suggesting that environmental cooling and airflow during motor operation contribute significantly to real-world thermal behavior—an aspect not fully captured in simplified simulation models. Furthermore, our findings indicate a nonlinear relationship between RPM and voltage drop, contrasting with the linear degradation pattern reported by Vetter et al. (2005) and Preger et al. (2020). These discrepancies highlight the importance of contextual variables, such as ambient temperature, motor efficiency characteristics, and real-time load variability. The comparison with simulation results also demonstrates that real systems face additional losses—such as inverter losses, cable resistance, and mechanical friction—not accounted for in idealized models, confirming the need for more adaptive modeling approaches as suggested by Lipu et al. [2].

Implications

CONCLUSION

The conclusions drawn from this study are as follows: 1) The effect of motor speed variation on battery current consumption in electric motorcycles is evident from the fact that higher motor RPM results in greater current consumption, which directly impacts the battery load during the discharging process and affects overall energy efficiency. 2) The effect of motor speed variation on battery thermal performance is shown by the increase in internal battery temperature at higher RPMs due to increased current, which can lead to

a reduction in battery lifespan if the system operates continuously without adequate cooling. 3) The effect of motor speed variation on battery life is indicated by the faster decline in battery voltage at higher RPMs, which implies a shorter battery runtime under high-load conditions. The recommendations for future research development are as follows: 1) Development of the model with variations in load and road conditions. 2) Comparison of the impact of different Battery Management System (BMS) configurations on thermal performance and energy efficiency. 3) Optimization of energy usage through control algorithms.

This study is limited by controlled experimental conditions and the absence of dynamic road load simulations. Future research should incorporate mixed driving cycles, ambient temperature variations, BMS-based thermal regulation, and real-time data logging to improve model generalization.

REFERENCES

- [1] K. L. Maheswari, S. Kavitha, and M. Kathires, "Introduction to electric vehicles and hybrid electric vehicles," in *E-Mobility: A new era in automotive technology*, M. Kathires, G. R. Kanagachidambaresan, and S. S. Williamson, Eds., Cham: Springer International Publishing, 2022, pp. 1–29. doi: 10.1007/978-3-030-85424-9_1.
- [2] M. S. H. Lipu *et al.*, "A review of state of health and remaining useful life estimation methods for lithium-ion battery in electric vehicles: Challenges and recommendations," *J. Clean. Prod.*, vol. 205, pp. 115–133, 2018, doi: 10.1016/j.jclepro.2018.09.065.
- [3] A. Pena-Bello, E. Barbour, M. C. Gonzalez, M. K. Patel, and D. Parra, "Optimized PV-coupled battery systems for combining applications: Impact of battery technology and geography," *Renew. Sustain. Energy Rev.*, vol. 112, pp. 978–990, 2019, doi: 10.1016/j.rser.2019.06.003.
- [4] R. T. Yadlapalli, A. Kotapati, R. Kandipati, and C. S. Koritala, "A review on energy efficient technologies for electric vehicle applications," *J. Energy Storage*, vol. 50, p. 104212, 2022, doi: 10.1016/j.est.2022.104212.
- [5] H. He *et al.*, "China's battery electric vehicles lead the world: Achievements in technology system architecture and technological breakthroughs," *Green Energy Intell. Transp.*, vol. 1, no. 1, p. 100020, 2022, doi: 10.1016/j.geits.2022.100020.
- [6] J. Piątek, S. Afyon, T. M. Budnyak, S. Budnyk, M. H. Sipponen, and A. Slabon, "Sustainable li-ion batteries: Chemistry and recycling," *Adv. Energy Mater.*, vol. 11, no. 43, p. 2003456, Nov. 2021, doi: 10.1002/aenm.202003456.
- [7] S. Hemavathi, S. Srirama, and A. S. Prakash, "Present and future generation of secondary batteries: A review," *ChemBioEng Rev.*, vol. 10, no. 6, pp. 1123–1145, Dec. 2023, doi: 10.1002/cben.202200040.
- [8] X. Zhang, Z. Li, L. Luo, Y. Fan, and Z. Du, "A review on thermal management of lithium-ion batteries for electric vehicles," *Energy*, vol. 238, p. 121652, 2022, doi: 10.1016/j.energy.2021.121652.
- [9] I. Laresgoiti, S. Käbitz, M. Ecker, and D. U. Sauer, "Modeling mechanical degradation in lithium ion batteries during cycling: Solid electrolyte interphase fracture," *J. Power Sources*, vol. 300, pp. 112–122, 2015, doi: 10.1016/j.jpowsour.2015.09.033.
- [10] M. Jafari, K. Khan, and L. Gauchia, "Deterministic models of Li-ion battery aging: It is a matter of scale," *J. Energy Storage*, vol. 20, pp. 67–77, 2018, doi: 10.1016/j.est.2018.09.002.
- [11] M. Ceraolo, G. Lutzemberger, and D. Poli, "Aging evaluation of high power lithium cells subjected to micro-cycles," *J. Energy Storage*, vol. 6, pp. 116–124, 2016, doi: 10.1016/j.est.2016.03.006.
- [12] W. Diao, S. Saxena, and M. Pecht, "Accelerated cycle life testing and capacity degradation modeling of LiCoO₂-graphite cells," *J. Power Sources*, vol. 435, p. 226830, 2019, doi: 10.1016/j.jpowsour.2019.226830.

- [13] M. Berecibar, I. Gandiaga, I. Villarreal, N. Omar, J. Van Mierlo, and P. Van den Bossche, "Critical review of state of health estimation methods of Li-ion batteries for real applications," *Renew. Sustain. Energy Rev.*, vol. 56, pp. 572–587, 2016, doi: 10.1016/j.rser.2015.11.042.
- [14] M. Yue, S. Jemei, R. Gouriveau, and N. Zerhouni, "Review on health-conscious energy management strategies for fuel cell hybrid electric vehicles: Degradation models and strategies," *Int. J. Hydrogen Energy*, vol. 44, no. 13, pp. 6844–6861, 2019, doi: 10.1016/j.ijhydene.2019.01.190.
- [15] H. Tian, P. Qin, K. Li, and Z. Zhao, "A review of the state of health for lithium-ion batteries: Research status and suggestions," *J. Clean. Prod.*, vol. 261, p. 120813, 2020, doi: 10.1016/j.jclepro.2020.120813.
- [16] A. Faraz, A. Ambikapathy, S. Thangavel, K. Logavani, and G. Arun Prasad, "Battery electric vehicles (BEVs)," in *Electric vehicles: Modern technologies and trends*, N. Patel, A. K. Bhoi, S. Padmanaban, and J. B. Holm-Nielsen, Eds., Singapore: Springer Singapore, 2021, pp. 137–160. doi: 10.1007/978-981-15-9251-5_8.
- [17] W. Liu, T. Placke, and K. T. Chau, "Overview of batteries and battery management for electric vehicles," *Energy Reports*, vol. 8, pp. 4058–4084, 2022, doi: 10.1016/j.egy.2022.03.016.
- [18] R. Zhao, S. Zhang, J. Liu, and J. Gu, "A review of thermal performance improving methods of lithium ion battery: Electrode modification and thermal management system," *J. Power Sources*, vol. 299, pp. 557–577, 2015, doi: 10.1016/j.jpowsour.2015.09.001.
- [19] J. Zhao, Z. Rao, Y. Huo, X. Liu, and Y. Li, "Thermal management of cylindrical power battery module for extending the life of new energy electric vehicles," *Appl. Therm. Eng.*, vol. 85, pp. 33–43, 2015, doi: 10.1016/j.applthermaleng.2015.04.012.
- [20] Y. Preger *et al.*, "Degradation of commercial lithium-ion cells as a function of chemistry and cycling conditions degradation of commercial lithium-ion cells as a function of chemistry and cycling conditions," *J. Electrochem. Soc.*, vol. 167, p. 120532, 2020, doi: 10.1149/1945-7111/abae37.
- [21] T. Y. Chian *et al.*, "A review on recent progress of batteries for electric vehicles," *Int. J. Appl. Eng. Res.*, vol. 14, no. 24, pp. 4441–4461, 2019.
- [22] Y.-W. Wang and C.-M. Shu, "Energy generation mechanisms for a Li-ion cell in case of thermal explosion: A review," *J. Energy Storage*, vol. 55, p. 105501, 2022, doi: 10.1016/j.est.2022.105501.
- [23] F. Ikhwan, "Analisa daya output sistem pengisian baterai pada sepeda motor hybrid dengan variasi putaran roda penggerak motor listrik berbasis arduino," Universitas Pancasakti Tegal, 2020.
- [24] A. Afzal *et al.*, "Thermal modelling and characteristic evaluation of electric vehicle battery system," *Case Stud. Therm. Eng.*, vol. 26, p. 101058, 2021, doi: 10.1016/j.csite.2021.101058.
- [25] A. Nekahi *et al.*, "Comparative issues of metal-ion batteries toward sustainable energy storage: Lithium vs. sodium," *Batteries*, vol. 10, no. 8, pp. 1–28, 2024, doi: 10.3390/batteries10080279.
- [26] P. Sun, R. Bisschop, H. Niu, and X. Huang, "A Review of battery fires in electric vehicles," *Fire Technol.*, vol. 56, no. 4, pp. 1361–1410, 2020, doi: 10.1007/s10694-019-00944-3.
- [27] J. Warner, "Introduction," in *The handbook of lithium-ion battery pack design*, J. B. T.-T. H. of L.-I. B. P. D. Warner, Ed., Amsterdam: Elsevier, 2015, pp. 1–8. doi: 10.1016/B978-0-12-801456-1.00001-4.
- [28] L. H. Saw, Y. Ye, and A. A. O. Tay, "Integration issues of lithium-ion battery into electric vehicles battery pack," *J. Clean. Prod.*, vol. 113, pp. 1032–1045, 2016, doi: 10.1016/j.jclepro.2015.11.011.
- [29] S. Atalay, M. Sheikh, A. Mariani, Y. Merla, E. Bower, and W. D. Widanage, "Theory of

- battery ageing in a lithium-ion battery: Capacity fade, nonlinear ageing and lifetime prediction," *J. Power Sources*, vol. 478, p. 229026, 2020, doi: 10.1016/j.jpowsour.2020.229026.
- [30] I. Viantama and B. M. Suyitno, "Comparative analysis of motor drive performance system in electric cars capacity 75 kwh," *J. Asimetrik J. Ilm. Rekayasa dan Inov.*, vol. 3, no. 2, pp. 157–164, 2021.
- [31] A. S. Martyanov, E. V Solomin, and D. V Korobotov, "Development of control algorithms in matlab/simulink," *Procedia Eng.*, vol. 129, pp. 922–926, 2015, doi: 10.1016/j.proeng.2015.12.135.
- [32] M. Müller and D. Pfahl, "Simulation methods," in *Guide to advanced empirical software engineering*, F. Shull, J. Singer, and D. I. K. Sjøberg, Eds., London: Springer London, 2008, pp. 117–152. doi: 10.1007/978-1-84800-044-5_5.
- [33] C. G. Thomas, "Experimental research," in *Research methodology and scientific writing*, C. G. Thomas, Ed., Cham: Springer International Publishing, 2021, pp. 93–133. doi: 10.1007/978-3-030-64865-7_5.
-

Copyright Holder :

© Arif Devi Dwipayana et al., (2025)

First Publication Right :

© Asian Journal Science and Engineering

This article is under:

CC BY SA