Performance Analysis of Lithium-Ion Batteries on Electric Bike With 350 W BLDC Motor

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Abstract: Developing automotive technology makes researchers pay more attention to carbon emissions produced by vehicles, therefore the energy transition from motorized vehicles to electric cars is a program that will be intensively carried out in 2023. Batteries are an important element as an energy source in Electric vehicles. Research on the use of Lithium-ion batteries for electric bicycles needs to be carried out to see the performance of the batteries used in electric bicycles. The electric motorbike in this study uses a 350 W BLDC Hub Wheel Drive motor with a 12 Ah Lithium-Ion Battery. The results of this research are the performance values for using Li-Ion batteries on electric bicycles.

Keyword : Performance, Battery, Lithium-Ion, Electric Bike, BLDC Motor

1 Introduction

Electric bikes have become increasingly popular for short-distance transportation purposes. The use of electric bikes can reduce emissions, air pollution, and traffic congestions in urban areas. An electric bike is powered by a battery that supplies energy to the motor. The performance of the battery can be affected by various factors such as battery capacity, motor power, and speed. The choice of battery type can also affect the electric bike's performance. It is important to study the performance of different battery types on electric bikes to optimize their use in urban transportation[1].

Brushless DC (BLDC) electric motors are now commonly used as the main drive system in electric vehicles. This motor combines a rotor designed with permanent magnets and a stator equipped with windings to produce a magnetic field [2]. BLDC motors are known for their high efficiency, reliability, and longer service life, although they are relatively more expensive. To electronically switch the polarity of a BLDC motor, a combination of a hall effect sensor and a rotary encoder is used [3].

In electric bicycles, the battery is one of the most important components which functions as the main energy source for the entire electrical system. It also functions as a storage medium for electrical energy during the charging process and powers various electrical components,

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including drive and lighting systems. Battery costs are a major obstacle to the widespread use of electric vehicles. In many electric vehicles, the battery is the most expensive component.

However, the use of electric bicycles still faces obstacles in terms of energy storage. These limitations stem from factors such as limited battery capacity and the absence of extensive electric charging infrastructure such as traditional gas stations for motorbikes. In addition, optimal utilization of battery capacity is hampered by constraints related to the depth of discharge value [4].

Recognizing how important the battery is as an energy storage device in an electric bicycle, further calculations were carried out to determine the appropriate battery capacity to power the bicycle, store energy, and facilitate efficient recharging. This effort aims to enable the sustainable and reliable use of electric bicycles with increased energy reliability.

2 Method

This study conducts a performance analysis of a 350 W BLDC motor using a Li-ion battery without the inclusion of a VRLA battery. The research methodology employed a field test approach, which involved measuring the electric bike's acceleration, speed, and distance traveled while utilizing the Li-ion battery. The Li-ion battery in this study featured a capacity of 12 Ah and a maximum motor current of 7 amperes, and the electric bike was subjected to different battery discharge rates, including 25%, 50%, 75%, and 100%, in order to comprehensively analyze the BLDC motor's performance.

Fig 1. Electric Bike

2.2 Brushless DC Motor (BLDC)

Brushless DC motors are a type of synchronous motor. This means that the magnetic field produced by the stator and the magnetic field produced by the rotor rotate at the same frequency [5]. This type of motor has a permanent magnet in the rotor and an electromagnet in the stator so that it does not experience slippage as happens in ordinary induction motors [4].

A brushless DC motor (BLDC) is a type of DC motor that does not have brushes. This motor has the advantage of better performance, reduced noise produced when rotating, cheap maintenance, and can rotate at high speeds due to reduced friction with the brushes. Meanwhile, the weakness of this type of electric motorbike is that the control is more complicated and the cost is more expensive [7].

Fig 2. BLDC Motor

This electric bicycle uses a 48V BLDC motor as the wheel drive. Hub wheel drive is the technology that will be applied to this electric bicycle. Hub wheel drive is a system where the BLDC motor is located on the tire rim of an electric bicycle. This is different from the mid-drive system which places the electric motor in the middle of the bicycle and then uses a chain to connect the motor and wheels [8]. The technical specifications of the BLDC motor are shown in Table 1.

Table 1. Brushless DC Motor Specifications

Spesification	Value
Voltage	48 V
Power	350 W
Max Power	> 350 W
Current	0-7 A
Max Current	7 A
RPM	0-500

2.3 Lithium-Ion Battery

Lithium-ion is a type of battery, which is rechargeable. Lithium-ion batteries use lithium compounds as one of the electrode materials. The advantages of lithium-ion batteries are as follows. Lithium-ion batteries operate at a higher voltage compared to other rechargeable batteries. They are characterized by their high energy density, low self-discharge, and excellent cycle life. Lithium-ion batteries are widely used in various applications, including consumer electronics, electric vehicles, and renewable energy systems. In particular, they are widely used in electric vehicles due to their high energy density, lightweight, and superior performance compared to other types of batteries. According to a study, lithium-ion batteries are predicted to dominate the market for electric vehicles due to their superior performance and growing demand [9].

The disadvantage of lithium-ion battery cells is that they are more expensive when compared to NiMh and NiCd battery cells. Then lithium Ion battery cells are not available in standard forms (AA, C, and D) cells like NiMh and NiCd cells [10]. One of the advantages of lithium-ion batteries for electric vehicles is their ability to store a large amount of energy in a relatively small and lightweight package.

Due to their ability to provide high power output, while reducing weight and size, Lithium-ion batteries are ideal for use in electric vehicles where they are suited for acceleration and handling. The use of lithium-ion batteries in electric vehicles is expected to increase due to their high energy density, long life cycle, and continued development of new materials and manufacturing techniques. [11].

Table 2. Li-Ion Battery Specifications

Specifications	Value
Nominal Voltage	48 V
Charge Voltage Range	52.5 - 54.0 V
Capacity	12 Ah
Energy	480 Wh
Max. Charge Current	20 A
Max. Discharge Current	20 A

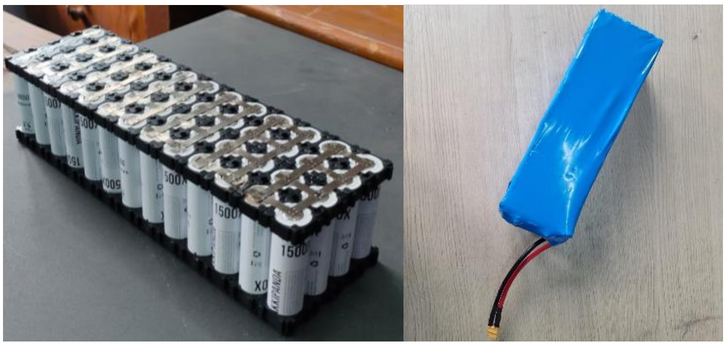

Fig 3. Lithium-Ion Battery Pack

3 Result and Discussion

From the experiments with no load that have been carried out, measurement results are obtained as in table 3.

Table 3. No-Load Test Results

Speed Level	Time (minutes)	RPM	Voltage (V)	Current (A)	Temperature (ºC)
Full Speed	10	460	52,6	1,1	30,3
	20	458	52,4	1,1	29,6
	30	456	52,2	1,1	29,3
	40	455	52	1,1	30,5
	50	453	51,8	1,1	30,3
	60	451	51,6	1,1	29,8
¾ Speed	10	339	51,5	0,91	30,3
	20	335	51,3	0,86	29,2
	30	331	51,2	0,89	30
	40	330	51,11	0,89	30,2
	50	326	50,9	0,89	30,2
	60	322	50,8	0,89	30,2
½ Speed	10	230	49,8	1,04	30,2
	20	225,4	49,52	1,02	29,4
	30	225,1	49,39	1,02	28,5
	40	224.4	49,20	1,04	28
	50	222,2	49,02	1,02	27,3
	60	221	48,8	1,01	27,8
¼ Speed	10	115	48,8	0.78	28
	20	113	48,6	0.79	27,9
	30	111	48,4	0.78	27,8
	40	109	48,2	0.77	27,9
	50	107	48,1	0.77	28,1
	60	105	47.9	0.77	27,9

In the first scenario, the RPM value starts at 460 RPM and gradually decreases to 451 RPM over 60 minutes, indicating the relatively slow rate of RPM decline and the ability of the motor and battery system to maintain a stable RPM during long-term use. The second scenario, with RPM values starting at 339 RPM and decreasing to 322 RPM, shows a significant decrease in RPM that may be caused by external factors such as increased load or challenging terrain, thus highlighting the need to address these factors to achieve optimal electric bicycle performance.

Likewise, the third scenario shows a significant drop in RPM from 230 RPM to 221 RPM, which likely stems from factors such as battery voltage fluctuations or external conditions. This underscores the importance of investigating and mitigating such variations to ensure consistent e-bike performance.

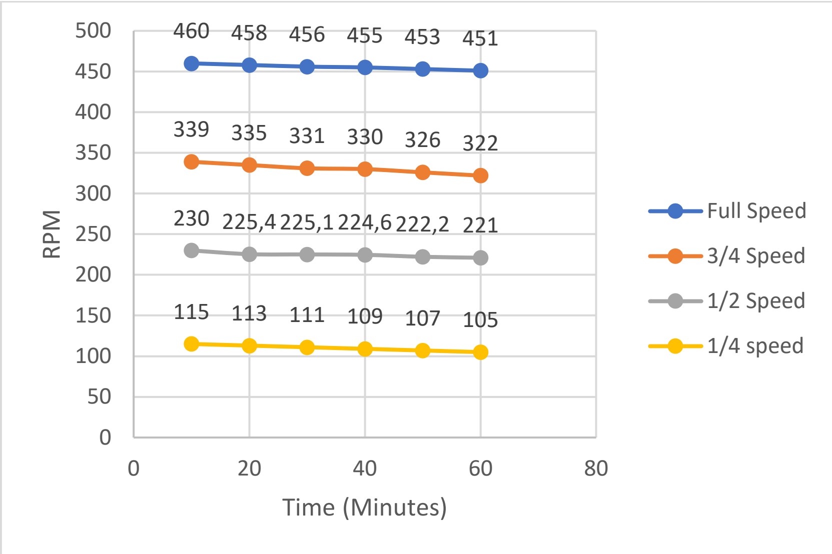

Fig 4. Graph of Speed Against Duration of Use

This scenario highlights the importance of closely monitoring and maintaining the performance of electric bicycles in real conditions. Maintaining a stable RPM is critical to providing a reliable and enjoyable riding experience. To achieve this, electric bicycle manufacturers and designers must consider a variety of factors, including motor efficiency, battery management, and load-carrying capacity. Implementing advanced motor control algorithms and predictive maintenance systems can help optimize performance and address RPM variations, ultimately increasing the appeal and practicality of electric bikes in a variety of environments.

When testing was carried out with a load of 1 passenger, the motor current increased significantly at constant speed. The test results are shown in Table 4.

Table 4. Battery Usage Time with Load

Working Current (A)	Speed (RPM)	Usage Time (Hour)
2	432	6
4	323	3
6	213	2

From this table, it can be seen that the amount of current affects the battery capacity. With a battery capacity of 12 Ah, it can be seen that with a current of 2 amperes and a speed of 430 RPM, the battery can last for 6 hours, then when the current is 4 amperes and a speed of 320 RPM the battery can last for 3 hours, then if the current is 6 amperes and the motor speed is 210 RPM the battery can lasts for 2 hours.

5 Conclusion

Through the tests that have been carried out, it is known that this research highlights the importance of monitoring the performance of electric bicycles. The first scenario shows a gradual decrease in RPM which indicates stable motor and battery performance. In contrast, the second and third scenarios show a more significant decrease in RPM, possibly caused by external factors such as field or battery fluctuations. This underscores the need to address these variables for optimal performance.

Overall, maintaining RPM stability is essential for a reliable driving experience. Electric bicycle manufacturers must consider factors such as motor efficiency, battery management, and load capacity. Implementing advanced control algorithms and predictive maintenance systems can help overcome RPM variations and increase the appeal of electric bikes in various environments.

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