The analysis of Li-ion battery pack 48V 15Ah performance for electric bike

Cite as: AIP Conference Proceedings **2708**, 070007 (2022); https://doi.org/10.1063/5.0123489
Published Online: 14 November 2022

Mohammad Ridho Nugraha and Evvy Kartini

The Analysis of Li-ion Battery Pack 48V 15Ah Performance for Electric Bike

Mohammad Ridho Nugraha [1, a)] and Evvy Kartini[1, b)]

[1]National Battery Research Institute
Edu Center Building 2nd Floor Unit 22260 Kav Commercial International School Lot. 2 No. 8 BSD City - Indonesia

[a)] Corresponding author: ridho.nugraha@n-bri.org
[b)] evvy.kartini@n-bri.org

Abstract. The main problems related to the E-Bike battery mostly appeared from the limited output power, due to the battery chemistry, the dimension, or the capacities. The output voltages from 12V until 48V of batteries are commonly used as the main supply. Aim of this paper was to design and built lithium-ion battery pack with the lightest and higher performance by applying 21700 NMC Cells. were designed and constructed. This battery pack will be placed in E-bike to power the 500W BLDC Motor. The output voltages of 48V, and the capacities of 15Ah were built from 39 cells of 21700 NMC, with configurations of 13 series and 3 parallels. In addition**,** the BMS was connected for protection and cell balancing features. The performance of the battery pack was analyzed using a Battery Testing Analyzer. The parameter of this study were the cell and pack charge-discharge capacity, C-rate dependence, and High C-rate capability. The output power from the battery is also measured in the dynamic condition while the motor running at a different speed. The results showed that the 21700 NMC 5000 mAh cell has a capacity of 4615.74 mAh (after 50 cycles) with 0.5C current. The 48V 15Ah battery pack delivered charge capacities of 13.28 Ah (1C), 13.70 Ah (0.3C), 13.61 Ah (0.5C), and a discharge capacity of 13.21 Ah (1C). It was capable of delivering the higher current up to 15 Amps (1C) during charge and discharge. At higher C-rates the amount of capacity inside the battery decreased, cell temperature increased, and the driving time of the E-Bike also could decrease. The NMC cells are capable of delivering higher C-rate performance to achieve high power and torque.

INTRODUCTION

Electric motorcycles have been developed into important vehicles over the past decade due to the transition energy from fuel to electric vehicles. Though sold and published by some as zero-emissions vehicles, there was little research to measure the environmental impact of electric motorcycles [1][2] . It measured some of the environmental impacts of the electric motorcycle manufacturing process and stages of use. Compared to other competing modes of transportation, such as bicycles, buses, motorcycles, and cars, The results showed that electric vehicles emitted far fewer pollutants per kilometer than internal combustion engine motorcycles and cars[3][4]Traction vehicles are a profitable solution in terms of cost and environmental cleanliness. Therefore, the use of electric power is very suitable for traveling in urban areas, because the vehicle mileage is relatively short in the city. Among electric vehicles in urban areas, bicycles are undoubtedly the least noisy and least polluting[5]. If electric vehicles (EVs) replace most gasoline-powered transportation, Li-ion batteries will significantly reduce greenhouse gas emissions. The high energy efficiency of Li-ion batteries also enables their use in a wide range of power grid applications, thereby contributing to their wider use and building a sustainable energy economy [6][7][8].

The electric bicycles (e-bikes) are much cheaper than other electric vehicles. "E-bike", was part of the classic power supply, for examples a muscle strength, was replaced by electricity, provides electric pedal support**.** In general, the e-bikes components consisted of an electric motor BLDC, an inverter and a battery pack. Earlier study by our group have successfully converted the conventional folding bike into the electric folding bike. In this study,

The International Conference on Advanced Material and Technology (ICAMT) 2021
AIP Conf. Proc. 2708, 070007-1–070007-6; https://doi.org/10.1063/5.0123489
Published by AIP Publishing. 978-0-7354-4283-2/$30.00

the performance of the battery pack will be analyzed in more detail. Li-ion batteries have advantageous, a combination of high energy and power density, making them the technology of choice for portable electronics, power tools, and hybrid/full electric vehicles. Therefore Li-ion batteries are in great demand by industry and government to fulfill the energy transition to net-zero emissions in 2060. There were various of materials used in Li-ion batteries, such as LiCoO2, LiFePO4, LiTiO, LiMnO, etc., but the recent demand for electric vehicles industries were the cathode containing nickel, cobalt and manganese (NMC) [9][10][8][11]. as Nickel-rich $LiNi_xCo_yM_{1-x-y}O_2$ ($0.8 \leq x < 1$, $0 < y < 0.20$, M= Mn, Al, etc.) layered oxide cathode materials exhibited superior discharge capacity (>200mAh/g) and voltage platform (3.6V). This superiority was deemed to be one of the most competitive candidates to traditional $LiCoO_2$ and $LiFePO_4$ [11][9]. Furthermore, the 18650-type cylindrical battery has been successfully applied in EVs of Tesla Model S, with the materials LiNi0.8Co0.15Al0.05O2 (NCA), providing a driving range of 270 miles per charge [9]. Increasing the capacities was done also by increasing the dimension of the cylindrical cell to the 21700-type cylindrical cell. The capacity significantly increased from the cylindrical types of 18650 to 21700, due to volume expansion. The aim of this study to design and build a Lithium-ion battery pack for conversion e-bikes, by using 21700 NMC cells in order to achieve the lighter and higher performance of the battery. The performance of battery pack 48V 15Ah will be analyzed via several parameters such as charge-discharge, cycles ability, c-rates, etc. by using a battery testing analyzer.

METHODOLOGY

Cell 21700 5000mAh NMC

The cells were used are 21700-cylinder cell types with the nominal voltage of 3.7V and 5000 mAh of their capacity. Each of the cells is inspected carefully from the voltage, cell internal resistance, and condition. The cell performance test was conducted by using NEWARE 8-Channel Battery Analyzer to collect the data related to real capacity in charge and discharge.

The 48V 15Ah battery pack was built with configurations of 13 series and 3 parallels, with the total 39 pcs of 21700 cells. The pack used the battery holders to ensure the safety and providing the gaps between the cells so that could act as cooling media. The connection between the positive and negative sides are connected with a pure nickel strip with 0.2 mm thickness.

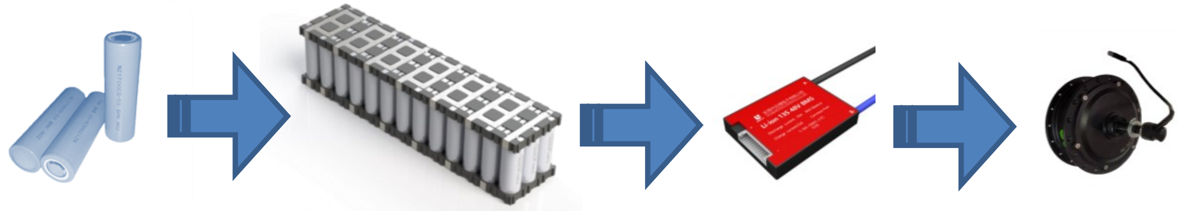

FIGURE 1. The battery pack assembly, BMS installation, and 500W BLDC motor for E-bike conversion

RESULTS AND DISCUSSION

A grading of the battery cells before packing into module was important step of the battery pack assembly. For this reason, all the cells were tested earlier [4][6]. Figure 2 showed the charge-discharge test of the NMC 21700 cell, which conducted with the parameter settings of 4.2V as charge cut-off voltage and 2.8V as discharge cut-off voltage. The current in this study used 0.5 C in the CCCV (Constant Current Constant Voltage) method for charging and CC (Constant Current) for discharging [10]. The total cycles were 50 cycles to collect the data for capacity retention of the cell. The result shows that the battery has a discharge capacity of 4615.74 mAh as shown in Table 1.

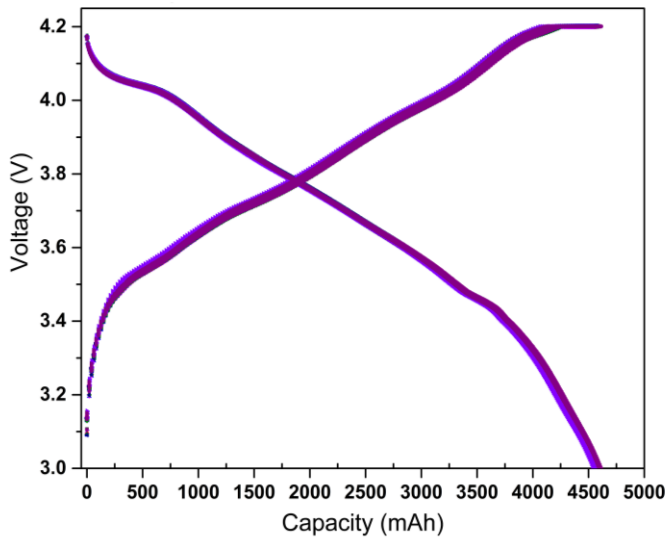

FIGURE 2. Charge-Discharge curve at 0.5C

TABLE 1. Discharge capacity after 50 cycles

Rated Capacity (mAh)	Capacity (mAh)	% Capacity
5000	4615.74	92.314

Before pack assembly, each cell has to be examined for the capacity, voltage and internal resistance in order to obtain equal quality performance. The cells were graded from the internal resistance values [6]. The measurement was done by a handheld battery tester. The result shows that the average internal resistance in each cell is 20.80 mΩ. Table 1 showed the results of voltages and internal resistance grading to the 21700 NMC cells.

TABLE 2. Internal Resistance Grading

Cell Number	Voltage (V)	Internal Resistance (mΩ)
1	3.615	21.46
2	3.613	17.455
3	3.613	20.19
4	3.615	20.19
5	3.613	22.24
6	3.617	23.3
7	3.615	20.83
8	3.619	20.26
9	3.612	20.26
10	3.613	20.21
11	3.615	20.26
12	3.615	17.849
13	3.613	22.04
14	3.615	22.82
15	3.615	18.17
16	3.613	22.17
17	3.615	24.78
18	3.617	23.44
19	3.613	15.789
20	3.613	20.19

Continued Table 2		
Cell Number	**Voltage (V)**	**Internal Resistance (mΩ)**
21	3.615	24.78
22	3.617	20.19
23	3.612	18.33
24	3.619	15.265
25	3.615	24.71
26	3.615	24.71
27	3.613	17.556
28	3.617	20.19
29	3.612	23.73
30	3.615	18.85
31	3.615	20.19
32	3.62	20.21
33	3.615	24.71
34	3.615	20.19
35	3.613	18.99
36	3.613	21.25
37	3.619	25.26
38	3.612	13.73
39	3.617	24.71
Average	**3.615**	**20.80**

Figure 3 showed the 48V 15Ah pack performance, conducted in a higher C-rate (1C). It is to prove that the pack can be used in a higher-rate condition and a faster charging time that required 1 hour to 100% full capacity.[12]. In 1C condition, this pack has a charge capacity of 13.28 Ah and a discharge capacity of 13.22 Ah.

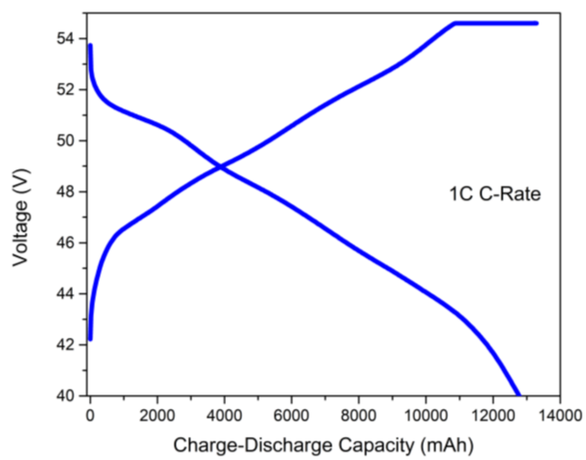

FIGURE 3. The charge-discharge curve of 48V 15Ah Battery Pack at 1C

The test was also conducted in variable C-rates to give actual conditions, when the bike used different speeds during driving. The C-rates and currents were 0.3C (5.122 Amps), 0.5C (7.701 Amps), and 0.7C (10.37 Amps). The result in Fig.4 showed that there is a certain loss when increasing the current. It can be compared also with the output power vs consumption time. It proved that the high C-rate usage will be decreasing the time consumption or it can say the battery can deplete faster.

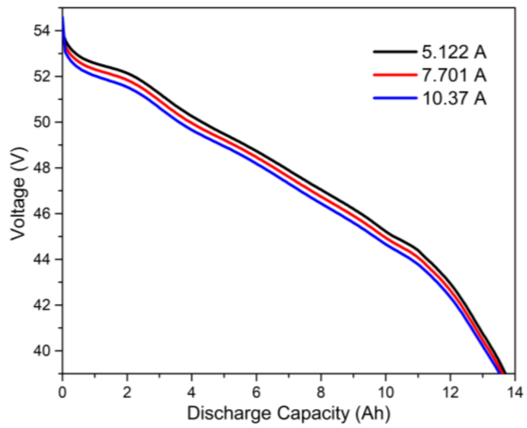

FIGURE 4. Discharge capacity at certain C-rate

TABLE 3. Discharge capacity at certain C-rate

C-Rate (C)	Discharge Capacity (Ah)
0.3	13.702
0.5	13.615
0.7	13.521

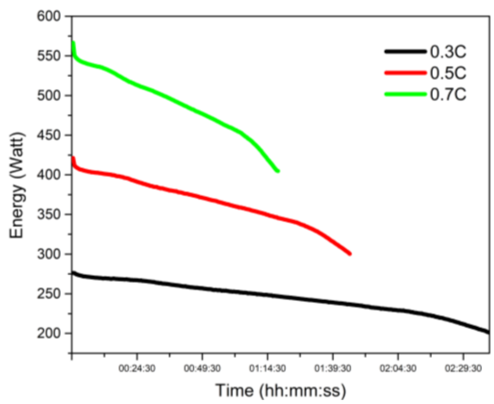

FIGURE 5. Output energy in certain C-rate vs time consumption

CONCLUSION

The battery pack of 48V 15Ah from 21700 NMC cells has been successfully assembled with the capacities of 13.615 Ah at 0.5C. The battery showed good performance, and it was capable of running in high C-Rate. The decreasing the amount of capacity inside the battery and driving time during e-bike riding could be avoided by using fixed c-rates at flat area. Higher C-Rate is still needed in the Electric Vehicle to achieve high power and torque when in the uphill road.

ACKNOWLEDGMENTS

The authors would like to thank the National Battery Research Institute (NBRI) for their financial support to do this research.

REFERENCES

1. I. Philips, J. Anable, T. Chatterton, E-bikes and their capability to reduce car CO2 emissions, Transp. Policy. 116 (2022) 11–23. https://doi.org/10.1016/j.tranpol.2021.11.019.
2. E. Kartini, Emerging battery research in Indonesia: The role of nuclear applications, in: B.A. Cunningham, O. Catherine, G. Shohini (Eds.), AIP Proceeding "5th Int. Conf. Women Physics, Waterloo, Canada, 5-8 August 2015"., AIP Publishing LLC, 2015: p. 100001. https://doi.org/10.1063/1.4937703.
3. F. Dewadi, U. Buana, P. Karawang, Frame e-Bike Optimization Capacity 48V, (2021).
4. D. Oeser, A. Ziegler, A. Ackva, Single cell analysis of lithium-ion e-bike batteries aged under various conditions, J. Power Sources. 397 (2018) 25–31. https://doi.org/10.1016/j.jpowsour.2018.06.101.
5. A.A. Kebede, T. Coosemans, M. Messagie, T. Jemal, H.A. Behabtu, J. Van Mierlo, M. Berecibar, Techno-economic analysis of lithium-ion and lead-acid batteries in stationary energy storage application, J. Energy Storage. 40 (2021) 102748. https://doi.org/10.1016/j.est.2021.102748.
6. E. Kartini, S. Sudaryanto, W. Honggowiranto, A. Sudjatno, A. Fadjri, I. Marto, R.N.S. Rofika, Grading of Lithium Ion Battery Module for Public street lighting, IOP Conf. Ser. Mater. Sci. Eng. 553 (2019). https://doi.org/10.1088/1757-899X/553/1/012065.
7. M.K. Saskia, E. Kartini, Current state of lithium ion battery components and their development, IOP Conf. Ser. Mater. Sci. Eng. 553 (2019) 0–9. https://doi.org/10.1088/1757-899X/553/1/012058.
8. W. Honggowiranto, E. Kartini, A. Purwanto, Electrochemical Performance of LiFePO4 Cylinder Cell Battery, in: AIP Proceeding (in Press., 2016.
9. C.M. Julien, A. Mauger, NCA, NCM811, and the Route to Ni-Richer Lithium-Ion Batteries, Energies. 13 (2020) 6363. https://doi.org/10.3390/en13236363.
10. B. Priyono, M.R. Nugraha, A.Z. Syahrial, Faizah, A. Subhan, Optimizing performance of Li4Ti5O12 nanorod doped C@ZnO by hydrothermal synthesis as half-cell lithium-ion battery anode, IOP Conf. Ser. Mater. Sci. Eng. 541 (2019). https://doi.org/10.1088/1757-899X/541/1/012025.
11. W. Yan, S. Yang, Y. Huang, Y. Yang, Guohui Yuan, A review on doping/coating of nickel-rich cathode materials for lithium-ion batteries, J. Alloys Compd. 819 (2020) 153048. https://doi.org/10.1016/j.jallcom.2019.153048.
12. J.M. Bhatt, P. V. Ramana, J.R. Mehta, Performance assessment of valve regulated lead acid battery for E-bike in field test, Mater. Today Proc. 49 (2021) 2058–2065. https://doi.org/10.1016/j.matpr.2021.08.305.