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Design of Battery Pack for Electric Bike

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Abstract. Recently, Electric Vehicles (EV) have begun to be produced massively, one of them is bikes or bicycles. Many bikes are produced due to the increasing market demand for bikes, especially during this pandemic. Peoples choose bikes because they are cheap vehicles, and also do not require any driving license. But in reality, the price of electric bikes is considered quite expensive, so many people prefer to convert ordinary bike into electric bike. One of the most important aspects in making an electric bike is the battery, which is the source of electric energy in electric bike. This study aims to explain the steps in designing a battery pack for an electric bike from a Lithium-ion Battery NMC21700 with a voltage of 3.6V and a capacity of 5Ah with dimensions of Ø21.25 × 70.8 mm. The expected result of the battery pack will produce the power of 720Wh. **Keywords:** *Battery Pack, Electric Bike, Design.*

INTRODUCTION

In response to the pandemic, COVID-19 has caused a sharp increase in bicycle sales. For a long time, cycling has been one of the fastest, most flexible and reliable means of transportation. When the stay-at-home order temporarily shortened daily life around the world, the role of bicycles changed [1]. As example in US, sales of bicycles have taken off in the US during the COVID-19 pandemic – they were up 65% between 2019 and 2020. The increase in sales figures does not only occur for conventional bicycle, but also occurs for electric bike. Electric bike sales grew by 145% in the same period [2]. This increase in sales of bicycle and electric bike are happening all around world, including Europe and Asia. Peoples choose electric bike because they offer low cost, energy efficient, and emission-free transportation which also has physical and health benefits.

One of the most important in electric bike is battery module or battery pack. There are many different types of battery usually use in electric bike, such as Sealed-Lead Acid battery (SLA), Nickel-metal Hybrid battery (NiMH), and Lithium-ion battery (Li-ion). Each type of battery has its own characteristics and advantages, but Li-ion battery has the most advantages over other types. Lithium-ion batteries can be charged hundreds of times and are more stable. Compared with other rechargeable batteries, it tends to have higher energy density, voltage capacity and lower self-discharge rate. This makes the power supply more efficient because the charge hold time of a single battery is longer than other battery types [3].

In this paper, we explain steps how to make the battery module using li-ion battery cells. The specification of battery module will be 48V 15Ah. The mentioned specification is chosen because has a high energy density so it is suitable for use on bicycles to keep the bicycle light but also able to use for long distances.

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METHODOLOGY

Materials

Lithium-ion battery is chosen as battery type for the module. The specification of li-ion battery that is use in this research is Lithium-ion Battery NMC21700 with a voltage of 3.6V and capacity of 5Ah with dimensions of Ø21.25 × 70.8 mm. Lithium-ion or li-ion battery has many advantages over other types of batteries like NiMH battery and SLA battery. The comparison of battery types is shown in Table 1 [4].

TABLE 1. The comparison of battery types.

Specification	SLA	NiMH	Li-ion
Life Cycle	200-300	300-500	500-1000
Energy Density	30-50	60-120	150-190
Self-Discharge/month	5%	20%	<10%
Fast-Charge Time	8-16h	2-4h	2-4h
Cell Voltage	2V	1.2V	3.6V

There are also several materials that needed beside battery to make a battery pack; Battery Management System or BMS for balancing the voltage of each cell, avoiding overcharge and overdischarge; battery holder to hold all battery cells; nickel strip for welding the cells according to serial and parallel configuration; insulation gasket paper to protect the positive and negative poles of the cells to prevent short circuits; fiberglass tape to keep the cells attached and protect the battery module when a short circuit occurs; PVC wrap heat shrink to wrap the whole battery module; the XT90 cable connector to connect the module to power; and the female jack DC cable connector to connect the module to the charger.

Design Model

For this study, we design a battery module with a voltage of 48V and capacity of 15Ah, so it has a power of 720Wh. Those specification are chosen because they have a big capacity so the bike can travel long distance, although have small size so the bike still light. One cell of li-ion battery NMC21700 has a working voltage of ±3.70V and capacity of ±5Ah. So, to make a battery module with 48v and 15Ah, it takes about 13 cells in series and 3 in parallel. The configuration of battery module is the cells are directly connected in parallel then assembled in series like shown in Figure 1.

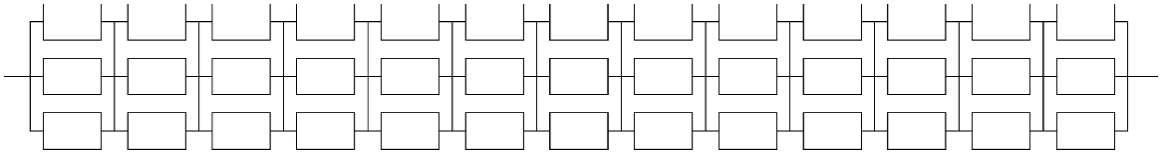


FIGURE 1. Battery module configuration with 13 series and 3 parallel.

This configuration is chosen based on research conducted by Federico Baronti and his friend (2014). They found that the battery configuration in which the modules are directly connected in parallel and then assembled in series is more resistant to changes in battery capacity. The results of this study show that the series connection of battery parallel modules provides the best connection topology because it maximizes the capacity of the battery pack and reduces the statistical dispersion of values [5].

RESULTS AND DISCUSSION

All the materials are to fabricate the battery module or battery pack. There are steps that must be done sequentially, so the result will be safe according to the procedure.

1) Measure the internal resistance value of every cells

Before start to put cells in accordance with the configuration, each of cell have to be measured its internal resistance value. Before the battery is measured, we put a number in each cell to make it easier to record the measurement results.

We measure a total of 85 batteries, the following are diagram of the results of measuring the voltage and internal resistance (IR) of each battery as shown in Figure 2.

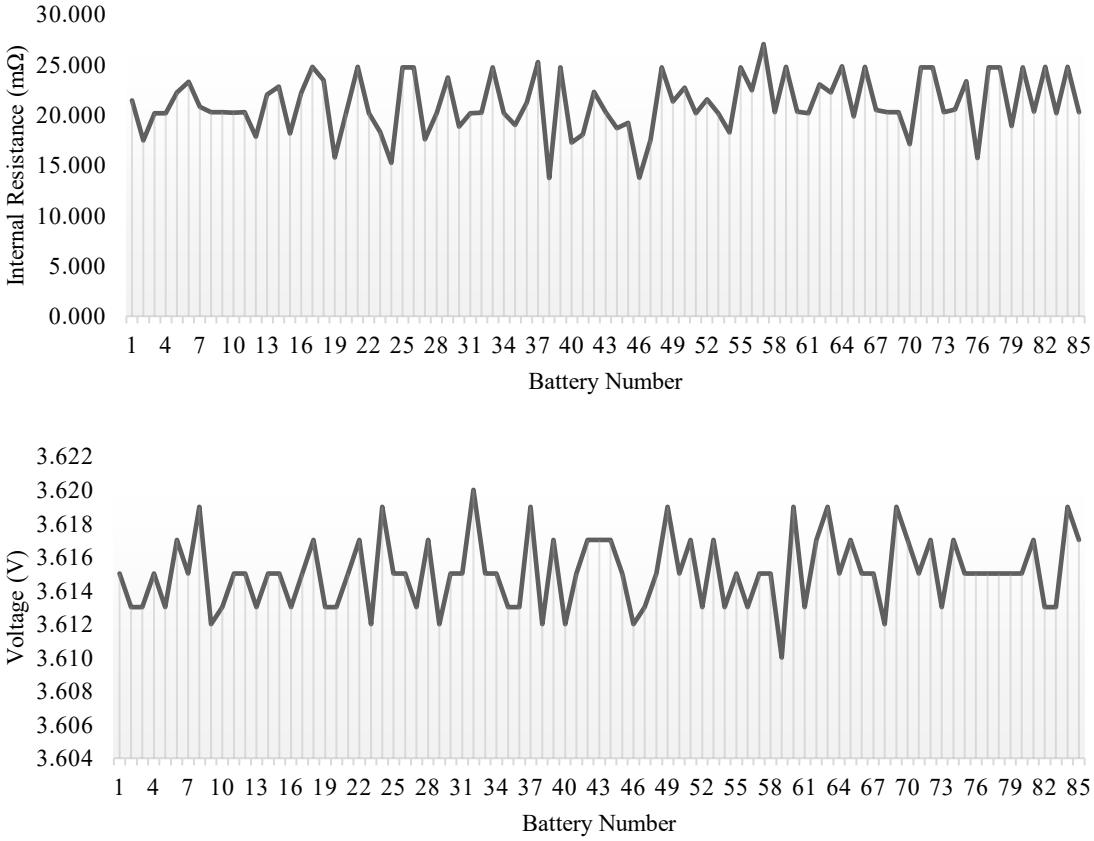


FIGURE 2. Diagram of voltage and internal resistance value.

Measuring the value of internal resistance is a very important aspect when arranging battery cells according to configuration, especially for parallel connection. This is based on the results of research conducted by Radu Gogoana and his friend (2014). They found that compared to two batteries connected in parallel with very similar internal resistances, a 20% difference in battery internal resistance between two batteries cycled in parallel resulted in a reduction in cycle life of about 40% [6].

2) Arrange the cells in series and parallel configuration

A battery module is obtained by connecting an appropriate number of battery cells in order to meet the voltage and capacity requirements. Batteries can be parallel connected to obtain a higher capacity or serially connected to create battery module with higher voltage. As mentioned before, to make a battery module with 48V and 15Ah using Li-ion NMC21700 cells, it takes about 13 cells in series and 3 in parallel. The cells are arranged so that the total internal resistance value of each parallel configuration is the same or close to each other. The following table shows the arrangement of the battery module configuration according to the results of the internal resistance measurement with the number of each cell.

TABLE 2. Battery module configuration based on the number of each cell

		Parallel Configuration		
		P1	**P2**	**P3**
Serial Configuration	**S1**	24	76	19
	S2	2	40	70
	S3	27	47	12
	S4	54	41	15
	S5	44	30	23
	S6	3	20	61
	S7	83	4	31
	S8	34	22	28
	S9	51	53	10
	S10	9	32	73
	S11	25	26	33
	S12	77	71	55
	S13	78	80	39
	Total	**262,366**	**262,443**	**262,358**

As shown in the table, the total internal resistance value of each parallel configuration is 262,366; 262,443; and 262,358. The difference in the total value of internal resistance for each parallel configuration is less than 1%. So, the configuration of the battery module will look like shown in Figure 3.

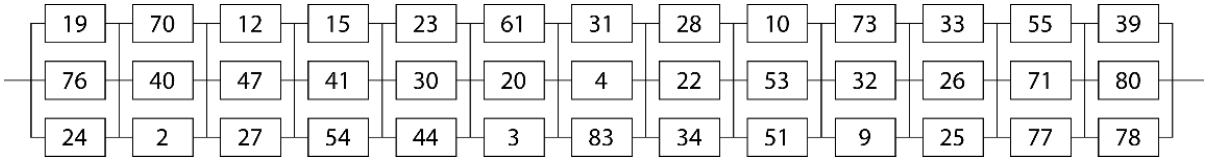


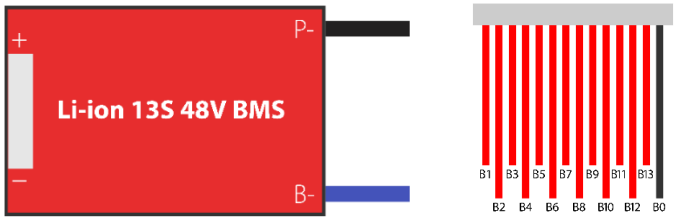
FIGURE 3. Battery module configuration with battery number.

3) Welding the battery module with nickel strips using spot welding machine

The battery module that has been arranged will be welding with nickel strips using spot welding machine. We used nickel strips with a thickness of 0.2mm as the current from the battery module is quite large. Extend the nickel on each positive pole of each series configuration of battery module. The extend is to make it easier to connect the battery module to the cable of BMS.

4) Connect the module to the Battery Management System (BMS)

Battery Management System or BMS is very important in battery module. BMS protects every cell in the battery module from overcharge and overdischarge so the battery module stays healthy and durable for long time. The application of BMS have to adjust to the battery module. The selected BMS specification corresponds to the number of serial configurations on the battery module. In this study we used BMS with 13S specifications.



(a) (b)

FIGURE 4. Battery Management System with 13S specification.

As shown in the Figure 4, there are parts of the BMS such as P-, B-, and B0 to B13; P- is connect to the negative output; B- and B0 are connect to the negative of battery module; and B1-B13 are connect to each positive of each battery module serial configuration.

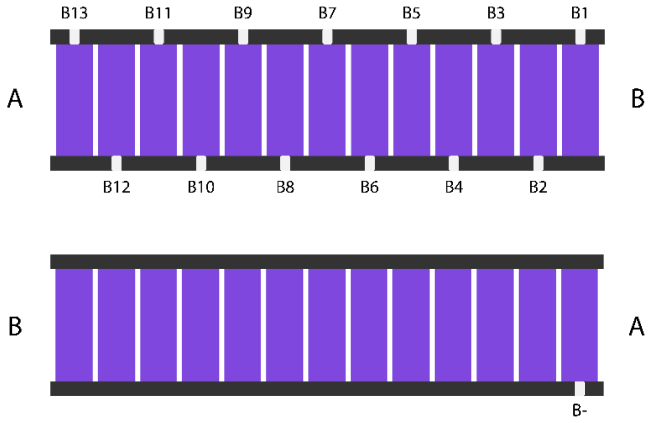


FIGURE 5. B0-B13 in the battery module.

5) Connect the module to XT60 and female jack DC connector

Connect P- to the negative and first positive of the battery module serial configuration to the positive of XT60 and female jack DC connector.

6) Wrap the battery module with PVC wrap heat shrink

Wrap the battery module with PVC wrap heat shrink for more protection for the battery module.

FIGURE 6. Wrap the module with PVC wrap heat shrink.

7) Finishing

After the battery module is wrapped, we measure the total voltage and State of Charge (SoC) of the battery module. The total voltage is around 46.9V with the remaining battery capacity is 40%. Then the battery module is charged until 100% and obtained a total voltage is around 53.9V. That total voltage is obtained because the maximum working voltage from an li-ion NMC21700 battery cell is 4.2V. So, if there are 13 cells in series, it will get a voltage around 54.6V.

FIGURE 7. The battery module after totally wrapped.

FIGURE 8. Voltage value of battery module after charged 100%.

CONCLUSION

There are several important steps when fabricating a battery module; first is measuring internal resistance of each cells so the battery module has a long-life cycle; and second, arranging battery cells directly connected in parallel and then assembled in series to have higher capacity. Also, the order of the methods in the battery packaging is important so the battery is completed and can work properly.

ACKNOWLEDGMENTS

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