Design of a 72 V 40 Ah Electrical System Battery Pack for Electric Motorcycle

1st Bandiyah Sri Aprillia
Department of Electrical Engineering
Telkom University
bandiyah@telkomuniversity.ac.id

2nd Desri Kristina Silalahi
Department of Electrical Engineering
Telkom University
desrikristina@telkomuniversity.ac.id

3rd Jangkung Raharjo
Department of Electrical Engineering
Telkom University
jangkungraharjo@telkomuniversity.ac.id

4th Mamat Rokhmat
Department of Electrical Engineering
Telkom University
mamatrokhmat@telkomuniversity.ac.id

5th Muhammad Ferdian Furkhan
Department of Electrical Engineering
Telkom University
ferdianfurkhan@student.telkomuniversity.ac.id

6th Fadli Abdul Syukur Wijaya
Department of Electrical Engineering
Telkom University
fadasw@student.telkomuniversity.ac.id

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***Abstract*— In Indonesia, there are many industrial electric motorcycle battery packs on the market with different voltages and different charging communication systems. This is because there is no standard used in Indonesia. However, currently many batteries circulating in Indonesia uses a voltage of 72 V with a capacity of 20 Ah. Therefore, this study aims to design a battery pack with a specification of 72 volts with a capacity of 40 Ah. The advantage of the results of the battery pack design in this study is that it has the same dimensions and weight as battery packs on the market but has twice the capacity of 40 Ah so that electric motorbikes can travel farther than those in circulation. Based on the research results of BMS monitoring, it is estimated that charging 100% at a voltage of 70.7 Volts. The difference in voltage in the battery management system and the results of the analysis calculations is caused by variations in the voltage in each battery cell. Technically the difference between each battery cell under 2 Volts will not be a problem as long as the BMS used has an active battery cell voltage balancing feature. In the dyno test results for each additional speed the battery can function properly at any given torque variation. In the next stage this battery pack can be used for electric motor vehicles to measure the maximum mileage.**

Keywords*— *electric motorcycle, lithium ion, battery pack, electric vehicle

I. Introduction

Currently, there are electric vehicle companies and assembly workshops in Indonesia that are capable of assembling electric vehicle batteries, but none have been tested or certified for safety. Standardization is very important, because conditions that do not meet the standard have potential to cause problems. The potential hazard of electric motor batteries is very important, statistics show that battery packs account for the highest percentage of explosions. These battery packs are used in electric motors [1].

There are many industrial electric motorbike battery packs that have been circulating in the market with different voltages and different charging communication systems. *Gesit* is a battery pack that is widely used in Indonesia and dominates the electric motorbike market with a voltage specification of 72 V and a capacity of 20 Ah. The charging time for *Gesit* is between 3 and 4 hours, with the first 30 minutes only being able to cover a distance of 10 km. *Gesit* claims that the motorbike can travel up to 50 km per battery. In Indonesia, *Gesit* is widely used by online motorbike taxis (Gojek). Unlike the grab motorbike taxi (GRAB), most of them use a Viar battery pack with a voltage of 60 V with a capacity of 20AH. The Viar battery pack is estimated to be fully charged in 5-7 hours with distances up to 60 km. There are several battery packs that are widely used by conversion electric motors, the voltage varies from 48 V, 60 V and 72. However, currently many battery packs circulating in Indonesia use a voltage of 72 V.

This research aims to design a battery pack with a specification of 72 volts with a capacity of 40 Ah. The superiority of the design results for the battery pack in this study is that it has the same dimensions and weight as the battery pack on the market but has twice the capacity of 40 Ah. In addition, the Battery Management System (BMS) in research is not only monitored on the user's Android screen but also has features capable of protecting each battery cell. Furthermore, prototypes will be made and tested in accordance with established standards and can truly meet safety in use.

II. Literature Review

A. Battery as Energy Storage

A battery is a device that converts chemical energy containing active materials into electrical energy through an electrochemical process of oxidation-reduction reactions [2], [3]. Batteries in electric vehicles are fundamentally different from batteries used in other applications. The basic difference between batteries in electric cars and batteries used in other applications is the amount of energy stored in the battery itself and the age of the battery product. Batteries for electric vehicle applications require greater energy and the product life of these batteries are longer than batteries used in electronic devices such as laptops, mobile phones and others [4]

Lithium batteries consist of elongated coils containing anode and cathode materials, which are separated by an insulating layer within the battery cell [5]. Additionally, there is a lithium-based electrolyte present between these layers, serving as a medium for transporting lithium ions. The separator allows the lithium ions to freely pass through while keeping the anode and cathode isolated [6].

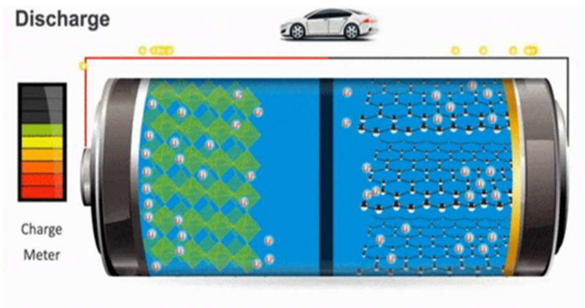

Fig. 1. Discharge process on Lithium Battery

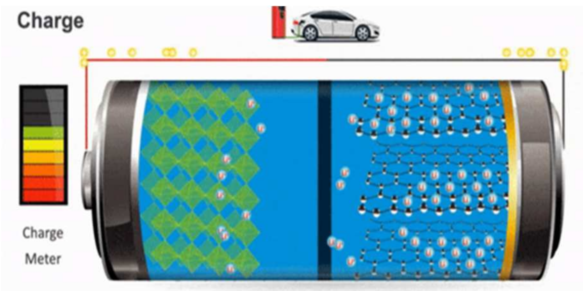

Fig. 2. Charge process on Lithium Battery

As the battery is discharged, lithium ions migrate from the anode to the cathode, facilitated by the electrolyte [7]. This movement creates an electrical imbalance on the cathode side, causing electrons to flow through the connected circuitry back to the anode, thereby supplying power to the device depicted in Fig. 1. During the recharging process, this sequence is reversed, and the lithium ions return from the cathode to the anode [8], as illustrated in Fig. 2.

B. Calculation for a 72 V 40 Ah NCM Battery

A 21700 Lithium battery has a nominal voltage of 4.2 V and a nominal capacity of 5000 mAh [9]. We can perform calculations in series and parallel as follows.

Fig. 3. Serial battery design

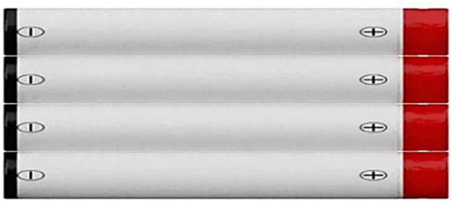

Fig. 4. Parallel battery design

In Fig. 3 the batteries are connected in series. When batteries are connected in series it will increase its voltage value. For this instance, a 72 V battery voltage is required, where each battery cell produces a voltage of 4.2 V, therefore as many as 17 series of batteries are required.

In Fig. 4 the batteries are installed in parallel. When batteries are installed in parallel it will increase its capacity value. We need a 40 Ah battery capacity, where each battery cell produces a capacity of 5 Ah (5000 mAh), therefore we need as many as 8 parallel batteries.

In assembling a 72 V 40 Ah battery, it takes 17 batteries in series and 8 batteries in parallel. The total battery used is 128 battery cells.

C. NCM Battery Assembly Procedure

The designs of lithium battery packs encompass various applications, including but not limited to electric bicycles, electric vehicles, backup power suppliers, grid solutions, and numerous other fields [10]. Battery assembly involves multiple stages, beginning with the preparation of essential components such as the NCM 21700 battery, battery bracket, nickel, insulator paper, PVC, BMS, and other necessary elements [11]. The subsequent section outlines the step-by-step process for assembling the NCM 21700 battery, specifically designed for a 72 V 40 Ah configuration intended for electric motor applications. The battery assembly process involves the following steps:

1. Battery preparation,
2. Stacking batteries in parallel (8p),
3. Welding batteries in parallel (8) on the positive and negative poles, resulting in a total of 17 connections,
4. Welding the battery in series (17S),
5. Conducting voltage measurements,
6. Installing the Smart BMS (Battery Management System),
7. Wrapping the battery pack,
8. Conducting comprehensive stress measurements,
9. Mounting the batteries onto the electric motor,
10. Performing the Dynotest,
11. Obtaining and analyzing the results of the Dynotest.

III. METHODOLOGY

A. Cylindrical Cell NCM Battery Assembly Process Flowchart

Fig. 5 illustrates the stepwise process involved in the assembly of NCM cylindrical cell batteries.

The process commences with the introduction of a new cell, upon which safety paper is applied to the positive side. Subsequently, the battery cell is examined using a multimeter to ensure proper function, followed by the installation of the battery bracket. Soldering is then performed, adhering to the specified voltage and Ah requirements, and thorough testing is conducted to assess battery performance. Once the entire battery has been tested, the BMS is integrated by connecting it to the battery while encased in PVC for safety purposes. To further enhance security, insulator paper is inserted, and PVC is correctly positioned. Following this, the battery pack box is formed, and the framework is installed. The assembled product then undergoes comprehensive testing to evaluate its functionality and durability. Subsequently, the battery pack is labeled and appropriately packaged. Finally, upon completion, the assembled batteries are dispatched to consumers.

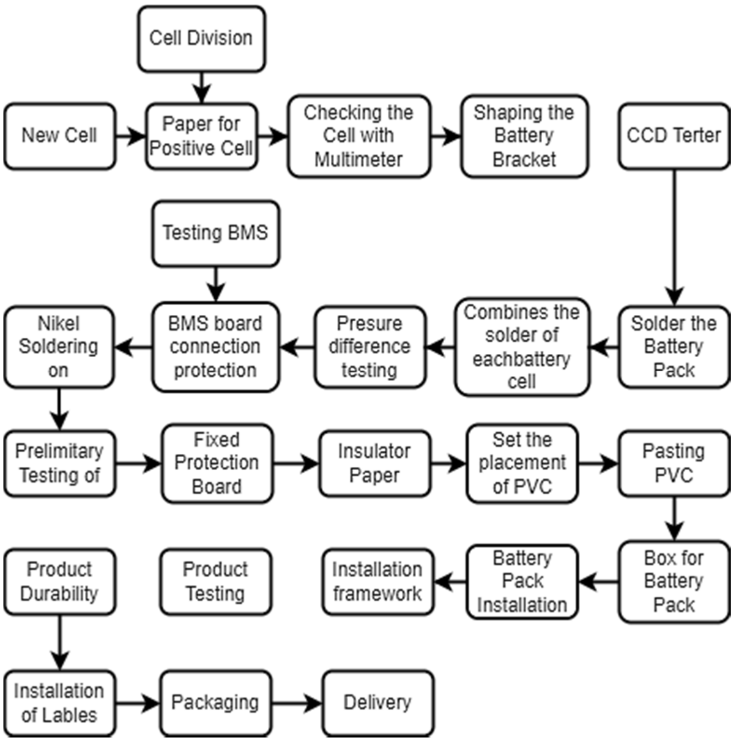

Fig. 5. Cylindrical Cell Battery Assembly Process Flowchart

B. *Hardware Design*

The design of a 72V battery pack with a capacity of 40Ah is as follows:

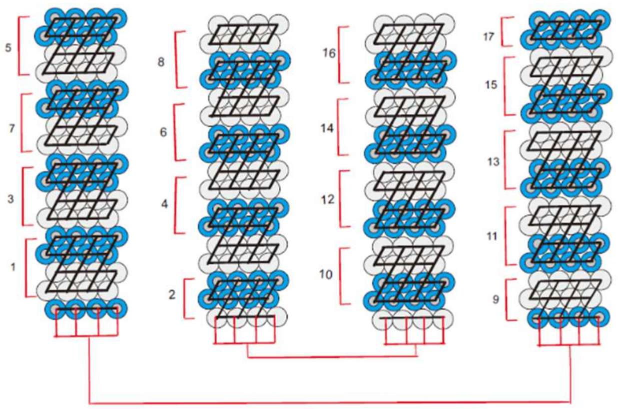

Fig. 6. Battery pack 17s engineering design

IV. Result

A. *BMS 17S 8P Battery Voltage and Capacity Test*

In the next step, connect to the BMS and monitor the battery pack voltage and capacity as shown in Fig. 7. Based on Fig. 7, the estimated charging is at 100% at a voltage of 70.7 Volts. In the system design analyzed if each cell is at 4.2 volts then for the 17 Series 8 Parallel circuit it produces 72 Volt 40 Ah. The difference in voltage in the battery management system is because there are still variations in the voltage of each battery cell as shown in Fig. 7. The maximum cell voltage is at 4.1198 V, the minimum voltage is 4.098 Volts and the average voltage is 4.158 Volts. If an analytical calculation is carried out using the average cell voltage then for 17 series the cell battery will produce 70.7 Volts as shown on the android monitoring screen.

Fig. 7. Voltage and capacity monitor results and State of Charge (SOC) results

Technically the voltage variation for each cell at 1volt to 1.5 volts can still be tolerated, but if the voltage variation for each cell reaches more than 2 volts then cell balancing can be done on the BMS feature or if the BMS cannot do balancing then in the early stages each cell can be fully charged until up to 4.2 Volts.

B. *Dynotest Testing*

At this stage, the dynotest testing is implemented, which serves as a method for evaluating the performance of car and motorcycle engines by assessing the power and torque outputs, ultimately determining the power capabilities of the prime mover. Presented below are the outcomes obtained from the dynotest testing.

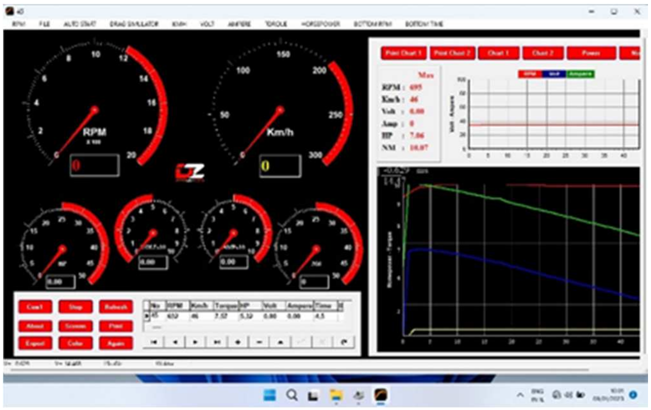

Fig. 8. Dynotest testing with gear 1

The dyno speed 1 test results describe the performance characteristics of a motorcycle or machine. With a rpm (rotation per minute) of 695, the vehicle or engine operates at that level. The speed reaches 46 km/h, while the power of 7.06 HP, this result reflects the power output of the engine, while the torque of 10.07 NM measures the rotational power of the engine.

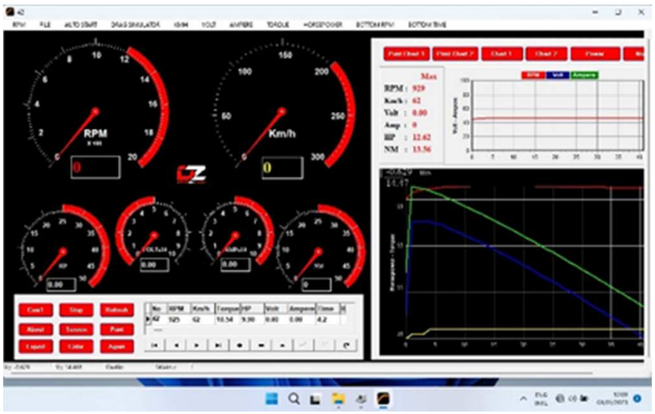

Fig. 9. Dynotest testing with gear 2

Fig. 10. Dynotest testing with gear 3

Based on Fig. 9, the results of the test dyno speed 2 at rpm (rotations per minute) reached 929, the maximum speed achieved was 62 km/h with a power output of 12.62 HP, this result reflects the potential power produced by the engine, and a torque of 13.56 NM describes the ability of the engine rotation in providing force.

Based on Fig. 10, the dyno speed test results at 1155 rpm (rotations per minute), the vehicle/engine rotates at that level. The speed reaches 77 km/hour, the power reaches 5.67 HP describing the engine power output, and the torque is 8.74 NM.

V. CONCLUSIONS

Based on BMS monitoring, the estimate is 100% charging at a voltage of 70.7 Volts. The difference in voltage in the battery management system and the results of analysis calculations is due to variations in the voltage in each battery cell. Technically, the difference between each battery cell below 2 Volts will not be a problem as long as the BMS used has an active battery cell voltage balancing feature. In the dynotest results for each additional speed the battery can function properly at each given torque variation. In the next stage this battery pack can be used for electric motor vehicles directly in the field to measure the maximum mileage.

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