Development of a High-Powered Compact Battery for Grass Cutter

Brylle Othmar R. Esmael, James Lloyd M. Gallego, John Morris Patrick S. Salado, and ***Jetron J. Adtoon**

College of Engineering Education
University of Mindanao, Philippines
*Corresponding author:
jetron.adtoon22@gmail.com

ABSTRACT

Burning fossil fuel contributes to today's global warming, such as automobiles, gasoline-powered machines, and other carbon emission activities. Gasoline-powered lawn-cutting machines are known to be powerful, bulky, and heavy. However, they will cost the environment in the long run, aside from requiring high operational and maintenance costs. Hence, in this study, a battery-powered hand-held grass-cutting machine was designed and fabricated using commonly available materials and technology. Essential aspects such as durability, capacity, and weight were considered in the design for better performance. The battery-powered grass cutter has a 26.5V lithium carbon rechargeable battery, which drives the D.C. motor and can operate for up to 4 and half hours in the field. Thus, the generated torque will be transferred to the blade for efficient, less noisy, and vibration grass cutting. The entire configuration setup was mounted on a metal pipe and PVC pipe. This handy lawn-cutting device can be maintained and trim grass in gardens, flowers, homes, schools, or yards.

Keywords: *lithium-ion, electrolyte potential, cycle, charge, discharge.*

INTRODUCTION

The globe is on the verge of significant consequences, such as global warming and greenhouse gas (GHG) emissions. It was produced by the widespread use of diesel and gasoline in vehicle operations, which emit tons of CO2 each year (Hannan, Azidin, & Mohamed, 2014; Hu et al., 2016; Sulaiman, Hannan, Mohamed, Majlan, & Wan Daud, 2015). Furthermore, rising crude oil prices are causing severe setbacks in the automobile sector, necessitating the development of alternative fuel-driven vehicles. Due to their excellent qualities in decreasing GHG, electric vehicles (E.V.) deployment has received much attention. It has become an attractive choice for academic researchers and automobile specialists to handle the issues (Abdul-Manan, 2015; Canals Casals, Martinez-Laserna, Amante García, & Nieto, 2016; Hofmann, Guan, Chalvatzis, & Huo, 2016; Poullikkas, 2015).

Grass cutters are currently the most used equipment for cutting or trimming grasses in lawns and fields. However, the bulk of these is powered by crude oil, which is becoming increasingly expensive to use as its price rises. As a result, the proponents devised a high-capacity battery as a cost-effective and environmentally friendly replacement for crude oil. Consequently, the user will find starting it up to be quite simple and convenient.

A battery is an energy storage device that uses electrochemical reactions to convert the chemical energy contained in its active components into electrical energy. A cell is the most fundamental electrochemical storage element. A battery comprises one or more cells linked in series, parallel, or both, depending on the nominal voltage and capacity required. This large-capacity battery includes lithium-ion, which has a high energy density, minimal self-discharge, and low maintenance requirements.

The battery's cells will be connected in parallel to boost the pack's capacity and fulfill the power and energy demands. Parallel connection of two cylindrical lithium iron phosphate (LFP) cells (Gogoana, Pinson, Bazant, & Sarma, 2014). It was discovered that a 20% variation in internal resistance resulted in a 40% loss in the useful life of a pair of cells compared to when the internal resistances were almost equal. The authors explain this to the cells' unequal current distribution. Their findings show that each cell will go through times of high currents, which will cause the cells to age more quickly (Gong, Xiong, & Mi, 2015). Similar conclusions were also reached from their experiments using 32 Ah cells. The peak current experienced when two cells with a 20% impedance mismatch were linked in parallel was 40% higher than if identical cells were. The authors also conducted simulation investigations, connecting two equivalent circuit models (ECMs) simultaneously using the Mathworks Simscape add-on to Simulink. This is one of the few documented examples of parallel cell modeling (Wang, Cheng, & Zhao, 2015). Simscape was also used to model cells in parallel, albeit the current distribution needed to be thoroughly examined.

Lithium-ion batteries (LiBs) are currently regarded as one of the most viable energy-storage technologies for electric and plug-in hybrid automobiles (PHEVs). Renewable energy sources such as solar and wind energy are intermittent and cannot be used where a continuous and consistent supply is required; hence, rechargeable batteries in E.V. applications have grown in popularity in recent years (Daud, Mohamed, & Hannan, 2013; Herrmann & Rothfuss, 2015; Shareef, Islam, & Mohamed, 2016; Yong, Ramachandaramurthy, Tan, & Mithulananthan, 2015). Many energy storages have been used in an E.V., including lead-acid, NiMH, and lithium-ion batteries (Manzetti & Mariasiu, 2015). This is due to lithium's lowest atomic weight and most significant negative potential.

The combination of lithium, carbon, and metal oxide produces electrical energy, but the lithium metal itself is highly reactive with air and liquid electrolytes. Before, lead-acid batteries were the most often used battery for vehicles and other battery-powered devices, but they could only provide a small voltage. As a result, the advocates studied the high-powered lithium-ion battery. This battery can deliver a high voltage to suit the lawn cutter's voltage or power requirements and run for several hours. Unlike other Li-ion batteries, this battery features proper insulation and protection circuits, either charging or discharging. In addition, reducing the risk of fires and explosions is an absolute safety need.

This research intended to create a high-capacity battery for grass cutters, which might be extremely valuable in isolated locations where crude oil is scarce. The researchers wanted to make a battery that could power a lawn cutter, has a long operating life, is low in weight, and is easy to transport. Since the environmental agencies have been promoting renewable energy and limiting the use of petroleum-based products, this research would assist such endeavors, especially because grasscutters have been proven helpful in daily operations in businesses and households.

METHOD

Research Design

The study made use of the applied research approach. Before conducting the actual fabrication, a trade-off analysis between the two designs was made. The analysis established the best design based on the study's objectives.

Materials and Resources

Batteries are a collection of one or more cell that creates a flow of electrons through their chemical reaction. The battery is primarily made to create portability for humans. It powers cellphones, flashlights, and remote-controlled devices and helps cars start quickly. It is part of our daily life and the convenience that batteries have brought led to the invention of more gadgets, appliances, and other equipment.

In the construction of the battery, battery elements are compiled from a negative electrode or copper foil as a current collector, separator or paper, and a positive electrode or lithium-coated aluminum foil as a current collector. It will be dried up to avoid moisture and stacked using a hydraulic press to obtain a smooth surface of the carbon material. Doing such will help improve electron movements and battery capacity. The battery is packed in each cell using plastic for inner insulation and connecting eight cells based on calculations to produce 26 volts. A melted glue stick and acrylic plastic for external insulation ensure the device's safety. The calculated life of the battery is 4 hours and 36 mins (276 mins) using the formula in (2) and getting 132.5 watt-hour capacity using (1).

This equation is used to determine the watt-hour capacity of the battery:

$$\boldsymbol{WHb = Vb * AHb} \quad (1)$$

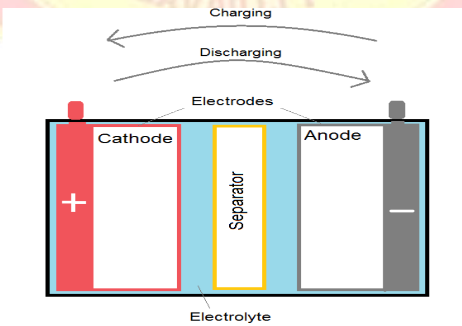
The equation for the total operation time of the battery with an hour to minutes conversion.

$$\boldsymbol{Thr = \frac{WH_b}{WHm} * \frac{60mins}{1hr}} \quad (2)$$

Methods and Procedures

Making a rechargeable battery entailed a variety of technologies and procedures to get the required voltage and ampere-hour. The first step was to acquire all necessary parts and tools. The second step was to choose the right or best carbon-coated aluminum product for your cathode, where significant companies are highly recommended. The third step was to make a copper foil. The copper foil must be very flat to achieve a more significant chemical reaction, which produces more electrolytes. The fourth component was the separator, which must be thin enough to separate both terminals and prevent a short circuit. The battery's voltage and capacity was expressed in Volts (V), Ampere-hours (Ah), or Watt-hour (Wh). Mix the pieces in a pleasant and orderly manner with all of the quality possible, then roll them up as much as possible to generate a more significant electrical reaction, raising the battery's voltage. Integrate all eight (8) pieces of open-circuit battery with an average of 3.3 volts per piece in series connection to meet the voltage requirement of the 24 VDC motor load, as shown in Figure 1.

Figure 1
Process Flow of a Single Open Circuit



The rechargeable high-powered compact battery is attached to the load with a 12,000 rpm 24VDC motor with 4 inches diameter 40 teeth thin metal blade in the shaft. The torque developed in the shaft is the product of force multiplied by the moment arm where force is equal to weight and the product of the blade's mass times the acceleration due to gravity, torque is inversely proportional to rpm, and due to the small amount of mass and short moment arm, it will not give significant changes in the revolution of the motor.

Function Testing Procedure

The tests were conducted along with the grassy areas of Pag-Asa Drive Matina, Davao City, since it was the most convenient for the research personnel. One thing considered in testing the battery was the safety of the user. By this, the proponents followed the IEC62133 (2nd edition) safety test standard of Li-ion cells and batteries to ensure the safety of the user as well as the success of the test. To measure the energy stored, the capacity test was conducted by charging and discharging the battery with time recorded based on the objective.

RESULTS AND DISCUSSION

Actual Design of the High-Powered Compact Battery for Grass Cutter

The high-powered compact battery is the primary focus of this study, having a capacity of 26.5 volts and a total of 132.5 watt-hours. The design is 24 inches cube in volume, has a mass of 1 kilogram, and can operate a load of 28.8 watts in four and a half hours. It has left and suitable polyvinyl chloride pipes as a holder for the operator to balance the device properly with the main switch on the right holder and supports the blade-carrying

D.C. motor. The control box contains the main electrical circuitry of the device placed above the battery and supported by a 1-inch diameter steel pipe body with a total length of 1.25 meters. The device's overall mass is 2 kilograms with a 4 inch-metal blade attached at the end, as shown in Figure 2.

Figure 2
Final and Actual Device

The 775 DC motor is attached to a 4 inch-diameter blade with an operating voltage of the D.C. motor 24V and a rated current of 1.2A with a speed of 12,000 RPM. It is supported by a plastic elbow pipe, as shown in Figure 3.

Figure 3
775 DC Motor & Blade

The control box has the charging and testing pin inside the box connected to the battery, testing 26.5 volts, the primary circuitry where an 8pins 24V relay and 24V PMW motor control with a 10-ampere fuse is located as shown in Figure 4.

Figure 4
Control Box

Data Analysis

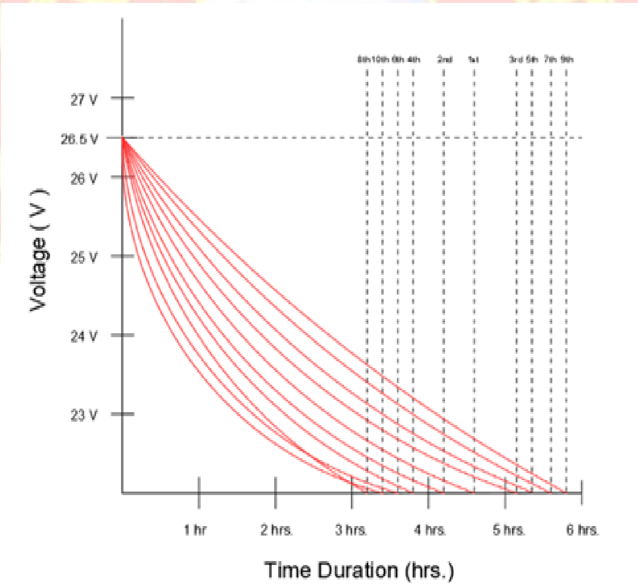
The researchers have observed the results and capability of the battery in the device after twenty trials of testing at different levels of capacity. The physical design is lighter and quieter than the traditional gasoline-powered grasscutter. The battery's electrode potential is well-calculated to operate outdoors for a couple of hours.

The battery's capacity is measured based on ampere-hour with 1.2 amperes required ampacity of the dc motor. The full-charged actual battery potential records 26.5 volts that operate for up to 4 hours and 33 mins (273 mins) as tested. Upon the panel of examiners' recommendation, the device should run up to 30 to 60 mins of operation.

The researchers have tested a total of twenty trials to determine the average discharge time of the battery at two different percent capacities. From the data from twenty successful trials, the resulting average discharge time of the battery at 100% total capacity of 26.5 volts is 273 minutes after ten trials, as shown in Fig. 5.

Battery Duration at 100% Capacity (26.5V) per 10 Trials

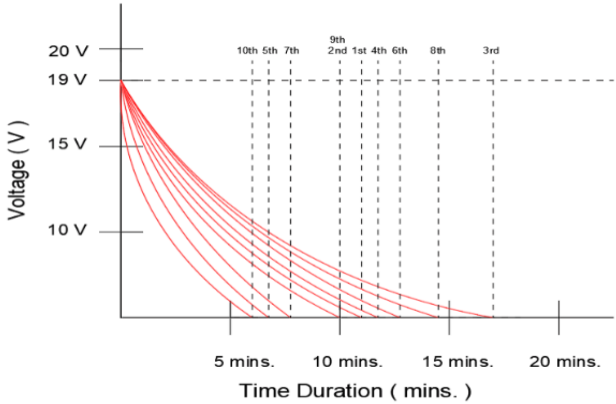
Figure 5
Time vs. Capacity Graph at 100 Percent



While in 70% capacity, around 19 volts, the gathered average data is 10.5 minutes of operational time, as shown in Fig. 6. There is a significant difference in operation time between the two different percent capacity levels due to under voltage. The rated voltage for the dc motor used in the device is 24 volts taking 19 volts from the battery source, which forces the dc motor to demand more amount of current to meet the power requirement of the load, causing the rise in temperature in the system and degrades the performance as well as the reliability of the motor which makes the motor not able to perform as it usually does. In electrical engineering, any temperature change is directly proportional to the resistance in the temperature coefficient of resistance (You, Wu, & Yang, 2016). Thus, as temperature increases due to low voltage, the resistance increases, and so as the voltage loss and power loss in the system, which affects the efficiency instead of producing operational output like torque. In summary, low voltage can affect the performance of the motor and the system, but with proper use of the device, it is safe to say that the 100 percent capacity of the battery can run for half a day of operation.

Figure 6

Time vs. Capacity Graph at 70 Percent



Thus, as per calculation, the study has 98.913 % accuracy in comparing the actual operation time to the theoretical operation time using (3).

$$\% \ \boldsymbol{Accuracy} = \frac{T_{min\ ACTUAL}}{T_{minTHEORETICAL}} x\ 100\% \qquad (3)$$

Result and summary of gathered data at different levels of percent capacity.

Table 3

Operation Duration in Minutes

	Operation Time (mins)
Mean (100% Capacity)	273 mins
Mean (70% Capacity)	10.5 mins

CONCLUSION AND FUTURE WORKS

In conclusion, the performance of the battery-powered grasscutter is satisfactory and sustainable. The appropriate design of the grasscutter was achieved. The High-Powered Compact Battery for Grass Cutter can operate lawn cutting in a reasonable time. The fabricated device had been effectively operating and could operate for up to four and a half hours in fully charged condition. Given the battery discharge duration, the researchers can conclude that the device is reliable and effective in cutting any grown grass. Not only efficient and dependable, but it is also very convenient to use. The device will be suitable for the operator to choose the desired direction or stroke in cutting grass because it is lighter than the traditional one.

It is recommended to make a mini-carlike grass-cutting device. With this, it will be convenient for the operator to use the machine in a more relaxed position instead of holding it for half a day. Also, it is recommended to include proper insulation to make it usable in any weather. Moreover, the researchers suggest improving its capacity to give higher power for extended usage in areas with no electricity, such as roads and highways.

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