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Selection and Analysis Performance of the Rechargeable Battery for Electric Go-kart Development

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Abstract: An electric go-kart engine powered by an electric motor must use electrical energy from batteries and not gasoline as a power supply. The use of gasoline does more harm than good, especially to the environment. Study research on this paper aims to identify the type of battery that suits the requirement of the go-kart electrical system and analyse the level of performance of the battery. There are many different types of batteries available, lead-acid and lithium-ion batteries chosen to narrow the selection range because both batteries are widely used and easy to find in the market. Discussions to determine the best aspect of each battery were conducted between group members and supervisors, and data results were recorded based on decision matrix analysis. Lithium Iron Phosphate (LiFePO4) battery branch for lithium-one has been selected based on the most significant total scale in the table decision matrix, which is 21 marks compared to the lead-acid battery, which only got 16 marks. The study also continued with performance analysis to discover the power consumption and the time taken for the battery from full charge to depleted according to three rotational speeds of the motor at 573 rpm, 1500 rpm and 2000 rpm. The results show that the higher the rotational speed of the electric motor, the higher the required voltage value. Hence, the power consumption will also increase because the power is directly proportional to the voltage. The study also discovered that the faster the motor rotates, the faster time for battery capacity depleted. However, the time is taken for the battery from full charge to fully discharge still exceeds 30 minutes even at the maximum rotational speed of the motor, which reaches up to 43 minutes. Therefore, this lifepo4 battery shows that it is the best selection for use in the manufacture of electric go-karts, either for 'fun kart' for recreation or 'race kart' for racing.

Keywords: Electric Go Kart, Rechargeable Battery, Power Source, Battery Capacity

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1. Introduction

Several batteries have been developed for various electrical appliances and rechargeable batteries, in general, are most important in manufacturing electric go-karts to provide power supply and stored energy. This will be the main problem if the selected battery does not match the required energy power of the go-kart, which will affect the electric speed of the motor and the durability of the discharge time for the go-kart system. It may cause the go-kart to be unable to move because the power provided is not enough to rotate the motor. This report will present an overview of the battery and charger specifications to ensure that the battery can be used in the electric go-karts development.

Rechargeable batteries, in general, are one of the most important in the manufacture of the electric go-kart. This part of the power supply will be the main problem if the selected battery does not match the required energy power of the go-kart, which will affect the electric speed of the motor and the durability of the discharge time for the go-kart system. Furthermore, it may cause the go-kart to be unable to move because the power provided is not enough to rotate the motor.

This study aims to identify the suitable rechargeable battery for electric go-kart applications in several battery attributes like output voltage, battery capacity, weight, mass, and cost. The second is to ensure that the power supply of the rechargeable battery is sufficient to move the electric motor. The third objective for this development is to analyse the power consumption of an electric go-kart is required. Lastly, the objective is to ensure that the battery can be utilised for 30 minutes from fully charged until exhausted.

Several parameters have been tested in this research project to see how well the selected battery performs towards an electric go-kart system. This focus area was done based on the following aspect the battery cell performance index involves a variety of variables such as the output voltage. Second, the circuit connections between the batteries in parallel or series are better for the real go-kart electric system. The performance of battery capacitive from full charge to discharge is also being analysed. Lastly, the charging rate depends on a low or high output voltage charger, and the preferred output current charger is recommended to the battery.

2. Battery Performance Characteristic

2.1 Voltage Requirements

The operating voltage is one of the critical parameters. Passivation may occur in specific battery systems. As a result, a reduction in the reactant (either the whole reactant or part of it) tends to form. Due to the limited electrical contact within the cell, this might severely slow the process.

2.2 Battery Capacitive

A battery's discharge performance depends primarily on the amount of load it must deliver. According to the manufacturer, suppose the discharge occurs over several hours, like a case in some high-rate applications. Then, the adequate capacity of the battery can be as much as double the indicated capacity at the C rate.

2.3 Charge/Discharge Cycle

A discharge/charge cycle is commonly thought to be the complete drain of a charged battery and subsequent recharge. However, batteries are rarely entirely depleted, and manufacturers typically rate batteries using the 80.00 % depth-of-discharge (DoD) method. That means only 80.00 % of the available energy is used, while 20.00 % will be held in reserve[1]. A charging cycle begins when the battery is attached and the program resistor is connected to the ground.

2.4 Physical Requirement

A battery must be chosen for a portable device depending on size and weight. Battery size decrease is expected for portable consumer gadgets, for instance. Additionally, batteries can add substantial weight to the device and increase power use in self-propelled applications [2]. Primary lithium systems offer double the energy density of rechargeable lithium-ion systems.

2.5 Overview of Chemical Reaction Selection

The preceding sections discussed the primary varieties of rechargeable batteries now in use and the future. The technical specifications for the most common kinds are listed in Table 1 to allow for a side-by-side comparison of several key aspects. In general, the selection of rechargeable batteries depends on several variables [3]. These characteristics include physical and chemical durability, storage capacity, operating temperature, self-discharge rate, discharge curve characteristics, price, safety, rechargeability, lifespan, charge time, and overcharge/over-discharge prevention [4].

Table 1: Characteristic of Rechargeable Battery Technologies [5]

	Specific Energy (Wh/kg)	Specific Power (W/kg)	Cell Voltage (V)	Cycles	Life (years)	Maximum Depth of Discharge	Self-Discharge Rate	Efficiency
Lead-Acid	35-50 [9]	150-400 [9]	2.1 [1]	250-1,000 [7]	5 years [7]	20-80% [1]	2-8%/month, some 20-30%/month [1]	75-85% [7]
Nickel-Iron	50-60 [9]	80-150 [9]	1.5 [9]	2,000 [10]	20 years [11]	80% [10]	20-40%/month [1]	
Nickel-Cadmium	30-60 [9]	80-150 [9]	1.2 [9]	1,000 to 50,000 [7]	10-15 years [7]	60-80% [1]	5-15%/month [1]	60-70% [7]
Nickel-Hydrogen	50 [9]	220 [9]	1.4 [1]	1500-6000 [1]	15 years [1]	-	Very high except at low temperatures [1]	-
Nickel-Metal-Hydride	60-80 [9]	200-300 [9]	1.2 [9]	300-600 [1]	2-5 years [1]	-	15-25%/month [1]	-
Nickel-Zinc	70 -100 [9]	170-260 [9]	1.6 [10]	up to 500 [10]	-	100% [1]	<20%/month [1]	-
Lithium-Ion	80-180 [9]	200-1000 [9]	3.05 [9]; 4.2 [1]	3,000 [1]	5+ years [1]	100% [1]	2-10%/month [1]	-
Sodium-Sulfur	150-240 [9]	230 [9]	2.71 [9]	2,500 to 40,000 [7]	-	100% [7]	-	86-89% [7]
ZEBRA	90-120 [9]	130-160 [9]	2.58 [9]	-	-	-	-	-
Vandium Redox Flow	0-30 [9]	100 [9]	1.2 [7]	10,000 [7]	7-15 years (estimated) [7]	100% [7]	-	85% [7]
Zinc-Bromine Flow	65-85 [9]	90-110 [9]	1.8 [7]	2,000 [7]	-	100% [7]	-	75-80% [7]
Zinc-Air	200 [9]	100 [9]	1.6 [1]	300 [38]	-	-	-	50% [38]

Lead-acid batteries, nickel-cadmium batteries, and nickel-metal-hydride batteries all have a more significant environmental effect. Since not all nations have established battery recycling facilities for all battery types [5], many contaminate end up in landfills closed with water and food supplies. Nonetheless, recent research has improved lead-acid battery recycling by recovering more lead and sulphate. Additionally, studies in China and India created a method for extracting cadmium and other heavy metals from batteries had conducted [6]. Such advancements can help to level the studying field in battery selection.

3. Methodology

This section conducts a systematic and theoretical analysis of the methods applied in this research field. The research method of the research chapter describes the methods and design details, focusing on the methods used in the fundamental research, and proves the rationality of the selection by describing the advantages and disadvantages of each method and design, considering the practical applicability of the research.

3.1 Flowchart

The approach flowchart depicted in Figure 1 will be utilised to guide the construction of this study. The beginning of this project is to get the literature review from another researcher's journal on how to start the project.

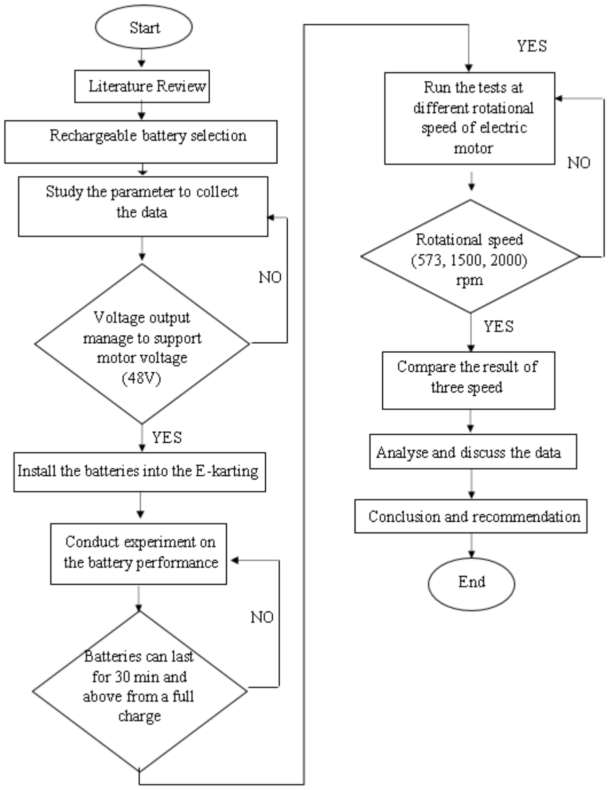

Figure 1: Methodology Flowchart

The step to do this project is to study the parameter to collect the data from the testing Electric Go-kart. The selected batteries will be connected either in parallel or series circuits to achieve the voltage level required by the electric motor. Then, each cell's voltage will be measured to ensure the cell has the same voltage value before the battery management system (BMS) is installed. Plug the batteries into the electric go-kart (E-karting) and ready to be tested. The experiment on the E-karting was run with the three rotating speeds of an electric motor as 573, 1500 and 2000 rpm. The data taken before the battery runs out were collected from the three experiments. After the experiment data have collected, the results of the three E-karting speeds were compared. The collected data was then analysed and discussed.

3.2 Battery Selection

Battery selection is based on brainstorming between group members and supervisors. This method was chosen because it is the best way to solve a particular commercial or technical problem, such as selecting. After all, new ideas will generate, and some knowledge will be shared for discussion.

Two types of batteries, namely lead-acid and lithium-ion, have been discussed. Only a few parameters are emphasised in making the comparison. The results of the discussion are translated into a decision matrix analysis. There are three scales in determining the selection, like the value of one (1) represents bad selection, two (2) for moderate and three (3) for best selection.

Based on the development of electric go-karts, the option to select rechargeable batteries for the category of electric go-kart systems was analysed using a decision matrix, as shown in Table 2

Table 2: Decision Matrix Analysis

	GP Battery (Lead Acid)		**LiFePo4 Battery (lithium-ion)**	
	Description	**Scale**	**Description**	**Scale**
Voltage	48V	3	48V	3
Capacity	28.8Ah	3	25Ah	2
Internal Resistance	1.9Ω	2	0.7Ω	3
Size	6.5cm(thickness) x 9.5cm(width) x 15.1cm(height)	1	2.7cm(thickness) x 7cm(width) x 13.5cm(height)	3
Weight	32kg	1	11.36kg	3
Life Cycle	≥260	2	≥2000	3
Price	RM608	3	RM992	1
Safety	-	1	BMS	3
Total		**16**		**21**

- 1 = bad selection
- 2 = intermediate selection
- 3 = best selection

3.3 Experiment Procedure

The experiment was carried out with three different rotational speeds of the electric motor, such as 573, 1500 and 2000 rpm. The rotational speed is measured by the Tachometer and controlled by the throttle pedal. This control variable guarantees that the researcher received diverse data with only three rotational speed tests, then examined for power usage. As a result, the experimental technique described below may be used:

i. Once the users assemble the components and parts of Electric Go-kart models, the battery cells will be placed on the go-kart on the backside. Make sure all of the battery cells must be appropriately stuck and firmly.

ii. Construct a wire connection between the battery cells with the loads (electric motor) and the charger. Make sure the wires are connected according to the correct label: a black wire for the negative terminal and a red wire for the positive terminal.

iii. The battery (LiFePo4) is attached to the controller, connecting to the switch, throttle pedal and electric motor.

iv. Switch on the electric go-kart. The speed of the Go-kart is varied to the minimum and maximum of the rotating electric motor. The data is collected. The data taken is in time, voltage and current to determine how long the battery can last and how much the power is consumed.

v. The data of the experiments of speed are recorded and stored in specified files and analysed.

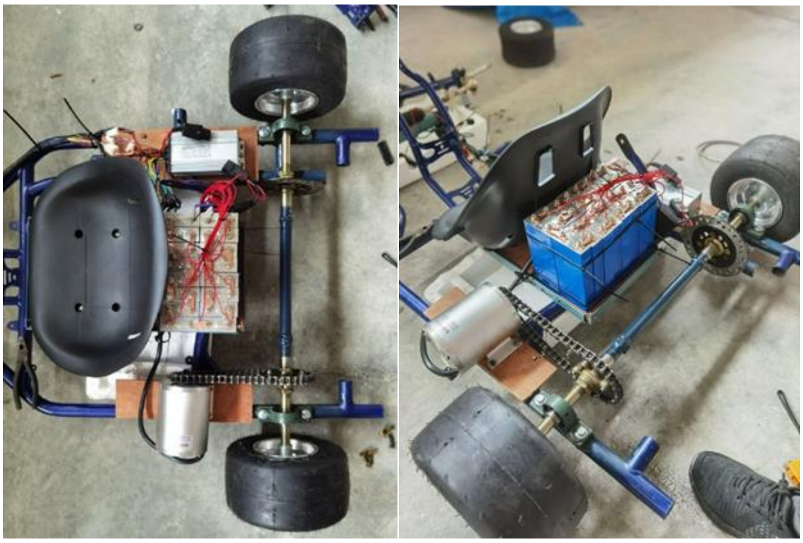

Figure 2: Position of the battery on the go-kart chassis

4. Results and Discussion

In this section, the findings of the experiments and research were presented. Data and calculations of specific aspects for the selected battery systems are based on theoretical formulas and experimental analysis. According to previous research, not all data are the same as experimental tests. Several elements, such as the resistance found in electrical wires, might impact data collection.

Based on the objectives of this study, the result will be to select the suitable rechargeable battery for electric go-kart applications in several battery attributes like output voltage, battery capacity, weight, mass and cost. After the battery was selected, data for analysing the battery performance like power consumption of an electric go-kart at 573 rpm, 1200 rpm and 2000 rpm were recorded. Thus, the battery is measured to either be utilised for 30 minutes from the time it is fully charged until it is exhausted or not.

4.1 Battery Specification

As shown in the figure below, Lithium Iron Phosphate (LiFePO4) battery has been selected to be used and installed on electric go-karts. This battery is selected based on the most significant total scale in the table decision matrix, which is 21 marks compared to lead-acid 16 marks. LiFePo4 battery-based innovation has a higher heat and chemical durability, which means it has excellent safety features than Lead-acid technology. Lithium Iron Phosphate (LiFePO4) are incombustible in the event of improper handling when charging or discharging. They are more stable in overcharge or short circuit circumstances.

Figure 3: 3.2 V 25 Ah LiFePo4 battery cell

The rating for the rechargeable battery used in this study is shown in table 3. A 3.2 V 25 Ah LiFePo4 battery cell was used to power the electric motor. This experiment had used several battery cells to become a battery pack.

Table 3: Specification for Battery Selected

Parameter	Descriptions
Name	Lithium Iron Phosphate (LiFePo4)
Voltage	3.2 V
Capacity	25 Ah
Dimension	27 mm (thickness) x 70 mm (width) x 135 mm (height)
Internal resistance	2 ohm
Weight	0.705 kg
Max upper voltage	3.65 V
Discharge lowest voltage	3.0 V
Max charge	1 C
Max continuous discharge	3 C
Max short discharge	5 C
Charging temperature	(0-40) ºC
Charging cycles	> 2000
Price	RM 62

Each cell battery supplies a 3.2 V and 25 Ah voltage as stated in the specifications above. 16 battery cells were connected, as shown in Figure 4, to supply the required voltage of the electric motor.

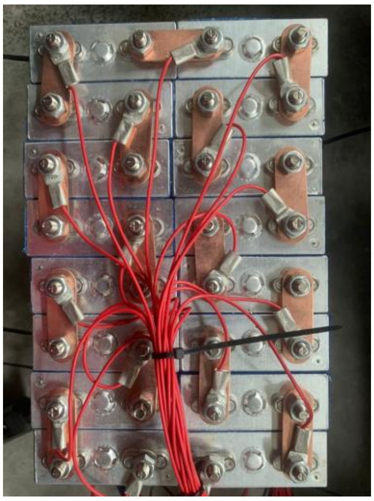

Figure 4: Series Connection

Total voltage of the battery = 3.2 V x 16 cells

= 51.2 V

Total weight of the battery = 0.705 kg x 16 cells

= 11.28 kg

Total size of the battery = 22 cm (length) x 14 cm (width) x 16.5 cm (height)

4.2 Battery Performance

The battery performance is analysed based on the voltage produced by each cell. Each cell has a low voltage value rate. A low voltage value rate might be why the battery will not supply the power required by the electric motor. Table 4 shows the output voltage by each cell after a complete charge (100% battery capacity).

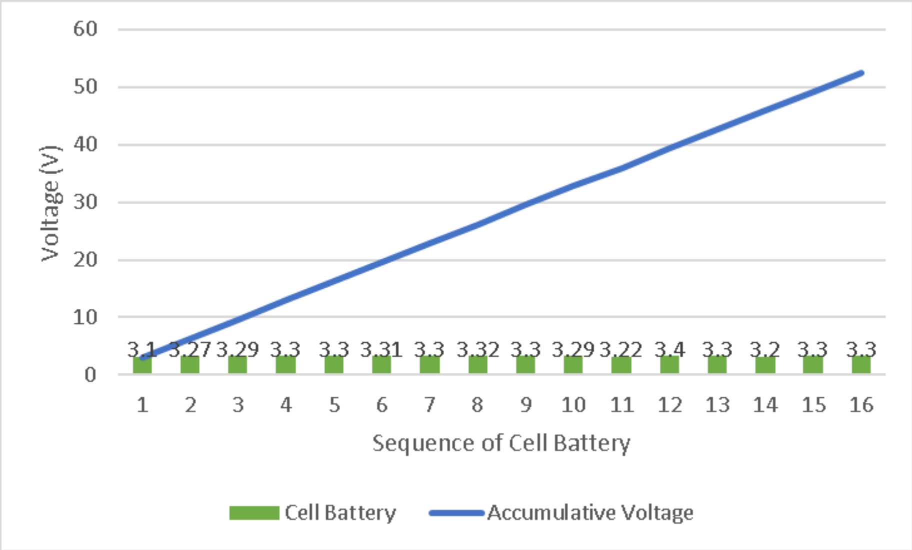

Figure 5: Output voltage for each cell battery

Based on the data obtained above, the total voltage produced by the battery to accommodate the electric motor is sufficient. The battery's output voltage can supply 52.5 v to the electric motor, only which requires 48v. However, one cell battery has a low voltage level at 3.10 v but does not affect the required voltage of motor electricity because the average voltage value is (52.50/16) = 3.28 v. Likely, the low-level voltage of the battery cell is in a high discharge value percentage.

Table 1: Data analysis

Rotational Speed Motor (RPM)	Voltage Required (V)	Power Consumption (W)	Time Taken Fully Discharge (min)
573	48.8	1610.4	48
1500	50.5	1666.5	45
2000	51.8	1709.4	43

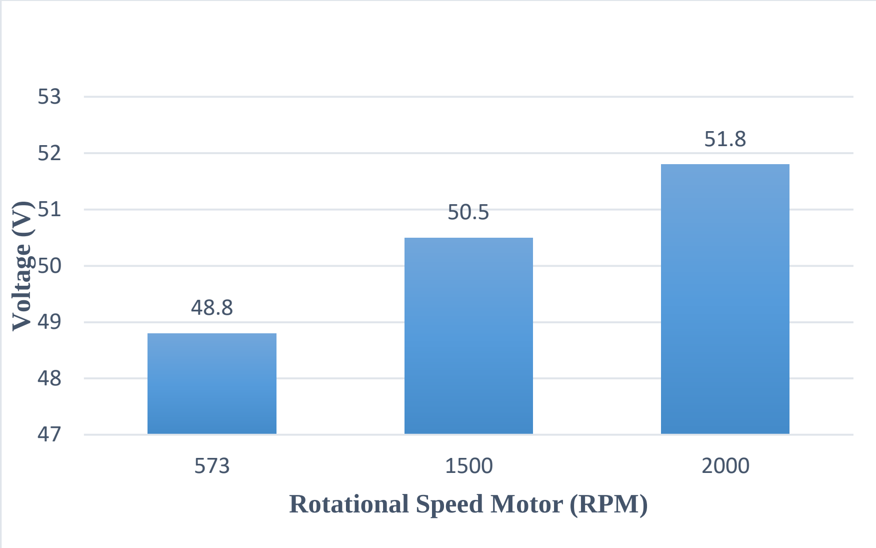

Figure 6: Required voltage versus speed of the electric motor

The graph in Figure 6 shows the voltage required by the electric motor from the selected battery (LiFePo4). The x-axis represents the number of rotational speeds of the motor, namely 573, 1500 and 2000 in rpm units, while the y-axis represents the voltage required by the motor. The trend shows that the higher the motor's rotational speed, the greater the voltage applied. This is because electric motors require more power to rotate faster.

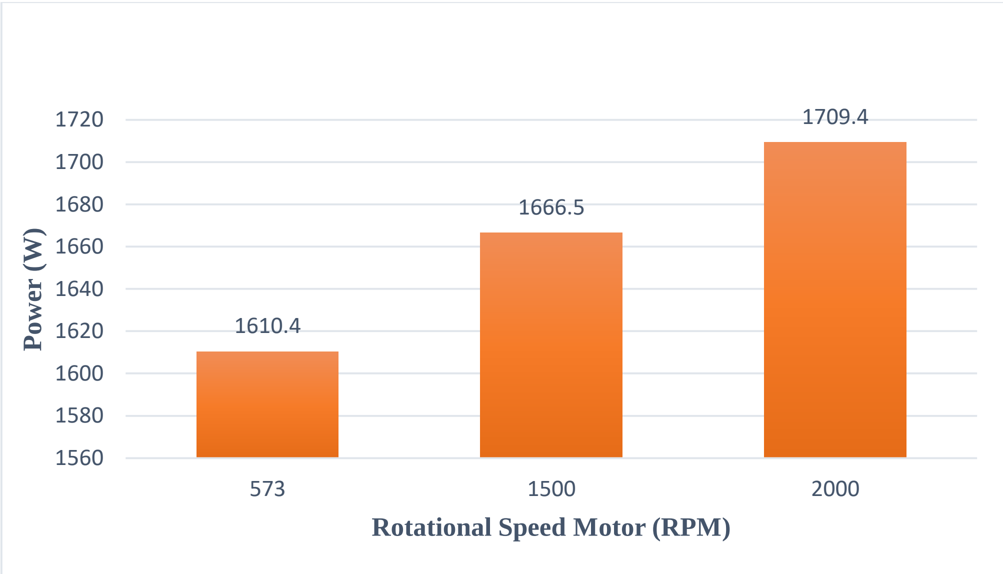

Figure 7: Power consumption versus speed of an electric motor

Based on Figure 7, the graph has shown the rotation of the motor speed against the power consumed. The x-axis represents several levels of motor rotational speed, namely 573 rpm for minimum 1500 rpm for average and 2000 rpm for maximum value. The trend shows that the more the motor's rotational speed, the more power will be used. This is because power affects the motor's speed, as the power-law states that power is equal to the voltage difference across the element multiplied by the current. So, if the rotational speed increases the voltage, the power will also increase.

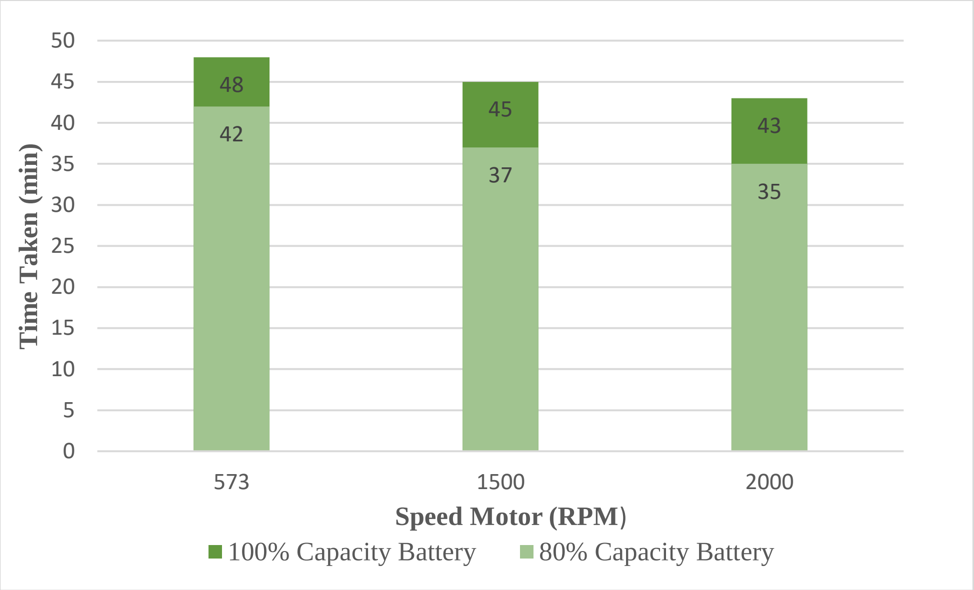

Figure 8: Time for discharge versus speed of the electric motor

Figure 8 shows a bar graph representing the x-axis of three motor rotational speeds, namely 573 rpm, 1500 rpm and 2000 rpm against the time taken from total battery capacity (100.00 %) to depletion (0.00 %) and also up to a point suggested by the previous study (80.00 %). The trend shows that as the rotational speed of the electric motor increases, the time taken for the battery capacity to reach its discharge level decreases. The time for the battery to run out depends on its use. The power from the battery will decrease, indicating that the battery is depleted.

LiFePO4 batteries can be discharged continuously to 100.00 % Depth of Discharge (DOD) without adverse long-term effects. That means 100.00 % utilisation without damaging the cell. 25AH get 100.00 % = 25AH capacity.

Estimate Battery Life = (51.2 V x 25 Ah) / (48 V x 33 A)
= 0.808 hour (48 minutes)

However, after 80.00 % of the battery capacity is discharged, charging is recommended to maintain battery life.

(80/100) x 25Ah = 20Ah

Battery Life = 20Ah / 33A
= 0.606 hour (36 minutes)

4.3 Battery Discharge Cycle

For this experiment, discharge cycle data were taken based on the voltage generated from a fully charged battery (0.00 % discharge) until the battery was fully discharged (100.00 % discharge). This experimental test was carried out by setting the angular speed of the electric motor to the highest value of 2000 Rpm. This ensures keeping the exact value of the current and voltage required by the motor while rotating.

Table 5: Depth of Discharge

Discharge Percentage (%)	Output Voltage (V)

0	52.5
10	51.8
20	51.8
30	51.8
40	51.7
50	51.7
60	51.6
70	51.6
80	51.5
90	51.1
100	48

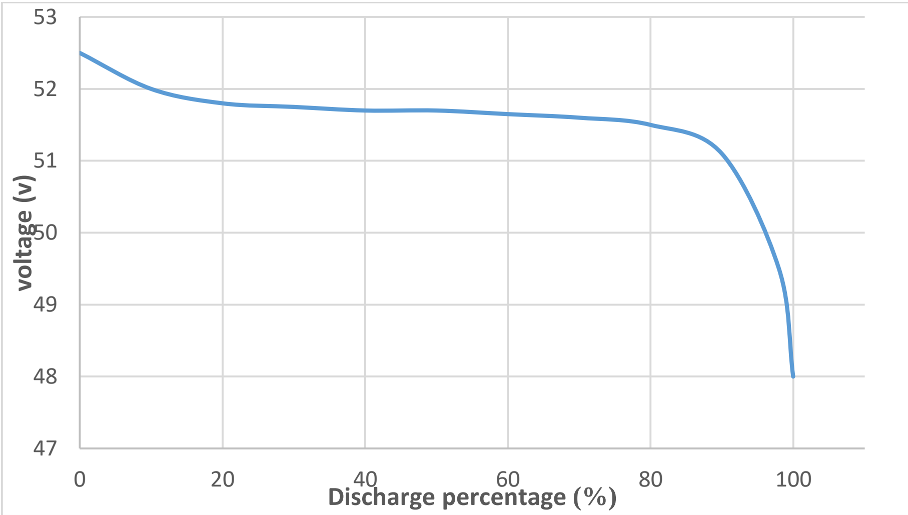

Figure 9: Output voltage vs percentage of discharge

From the recorded data, the graph was plotted according to the voltage against the discharge percentage as in Figure 9. the pattern of the graph shows a decrease, and there are at some value points where the graph is flat at a specific discharge percentage. This can be shown at a discharge value of 10.00 % to 70.00 %, where the voltage required by the motor to reach and be consistent at the maximum angular velocity level is still adequately supplied by the battery voltage.

4.4 Charging Rating

The charging rating is analysed depending on the current flowing out of the charger. The charger's output voltage value is the same as that of the battery. So, no evaluation was done because there was no difference. Figure 10 represents the charger selected for the LiFePo4 battery. This charger also works to convert alternating current to direct current.

Figure 10: Selected charger

Charge/Discharge: （CC/CV)
Voltage Output = 54.6 V
Current Output = 10 A

Battery $voltage_{max}$ = 3.65 V x 16 units = 58.4 V

Charger voltage output is suitable because it ranges between
(58.4 V < 54.6 V < 51.2 V)

Current charger, max charger : 1 C = 25 A
recommend charger : 0.5 C x 25 Ah = 12.5 A

The selected charger current 10 A is not too high or too low. The excessive current causes electrochemical processes to accelerate (increase) when the temperature rises, resulting in more significant ion and local particle movement (resonation) inside the materials, resulting in the increased internal resistance of the battery. Indeed, a low current will increase the time required to charge completely.

Charging Time = 25Ah / 10A

= 2.5 hours (2hours 30 minute)

5. Conclusion

In this research, Lithium-ion batteries were selected based on group discussions to proceed with performance testing. All the objectives in this project study have been achieved. The resulting results are based on formula calculations and experiments. Firstly, the battery results meet the 30 minutes, which is the minimum requirement for a Go-kart circuit, and the battery can run up for 48 minutes from the total charge to fully discharged. This can serve as a guideline to researchers and developers in go-karts.

Among the aspects that need to be given priority is such as voltage because it plays a role in whether the power produced is sufficient with the power required by the go-kart electrical system, especially the motor. The result shows that the faster the electric motor's rotational speed, the battery will consume more power. In addition, the faster the rotational speed of the electric motor also affect the time for the battery to be exhausted. For lower rotational speed as 573 rpm, the battery can last up to 48 minutes compared to the full speed of 2000 rpm; the battery lasts up to 43 minutes. The matter of battery capacity should be taken into a priority in choosing a battery because it determines the time for the battery to be used from full charge to depletion. The way of use also plays a role, as the higher the power consumption, the faster the battery to run out before being recharged again.

Next, charger selection is also essential because inappropriate selection can result in the charger being unusable and not matching the chemical battery type or the charging process. Still, it will take longer for the battery to reach total capacity. The charger current is 10 A, where the time is taken to charge the battery from depletion to complete about 2 hours 30 minutes. Unsafe manners like inappropriate voltage and current such as too high will cause the battery temperature to rise and explode.

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