Multidisciplinary Applied Research and Innovation Vol. 3 No. 5 (2022) 68-75

MARI

Homepage: http://penerbit.uthm.edu.my/periodicals/index.php/mari
e-ISSN: 2773-4773

Powertrain Design and Simulation for an Electric Go-Kart

Aiman Omar[1], M. Haziq Zull Azri[1], Siti Nuraisyah Sairan[1], Mahmod Abd Hakim Mohamad[2*], Mohd Faisal Hushim[3], Yahaya Ramli[4]

[1]Department of Mechanical Engineering, Centre for Diploma Studies, Universiti Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, 84600, Pagoh, Johor, MALAYSIA

[2]Sustainable Product Development (S-ProuD), Centre for Diploma Studies, Universiti Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, 84600, Pagoh, Johor, MALAYSIA

[3]Centre of Automotive & Powertrain Technology (CAPT), Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, Pagoh Higher Education Hub, 84600, Pagoh, Johor, MALAYSIA

[4]Department of Thermo-Fluid, Faculty of Mechanical Engineering, 81310 Universiti Teknologi Malaysia, Skudai, Johor, MALAYSIA

DOI: https://doi.org/10.30880/mari.2022.03.05.010
Received 15 July 2022; Accepted 30 November 2022; Available online 31 December 2022

Abstract : Replacing fuel with electric would be benefited for the environment, as fuel which has been widely used as main sources of energy, contributes to the world carbon footprint and it is increasing per billions over the year. To overcome this issue, electric powered go-kart is using DC motor and DC power supply batteries is developed. Simulation and 3D printing are applied to find the optimum configuration for the powertrain and its performance to be tested. In this investigation, a total number of 16 packs of 3.2V LiFePO4 batteries, a 48V DC2000W brushless motor, a motor controller and a battery management system are used and mounted on a go-kart chassis. The CAD model of the powertrain is designed in a smaller scale and simulated prior the rapid prototyped to test the integration of the powertrain in a smaller scale to reduce the cost implication. It is found that the powertrain is able to perform for 30 minutes using full power without any malfunction effects to the components. There is no evidence of overheating with decreasing of 0.6V per 10 minutes. In conclusion, the objective of this project are satisfied and suggestion for future work is to test the actual performance of the powertrain in the circuit. The go-kart however, must be in ready-to-race condition for safety measure.

Keywords: Electric Go-Kart, Simulation, Powertrain, LiFePO4, DC2000W

**Corresponding author: hakim@uthm.edu.my*

1. Introduction

A go-kart is a low and light motorized racing car with a small open-wheel frame called a kart or go-kart, depending on its design. The vehicle has two misaligned wheels that steer and one that provides power. It can be powered by either gasoline or electric power [1]. A real method for transferring power from the engine to the tyres is a transmission system. But it alters somewhat with an electric go-kart. An electric go kart transmission system is made up of several main power transmission components such as a battery (power supply), a motor (prime mover), two sprockets, a chain, and the axle of transmission [2].

The problem with gasoline, it is one of primary and current sources of energy and that widely used, is proven to increase environmental problems with regards to carbon footprint. In order to improve the environmental state of the world, an immediate proactive measure must be taken by users by exploring other alternatives fuel which is electric source of energy [3].The annual carbon dioxide emission from a typical passenger automobile is around 4.6 metric tonnes as shown in **Figure 1**. This outcome might be varied according to the fuel efficiency and annual mileage of an automobile. In general, any electric powered vehicle or commonly known as electric vehicle (EV) will not contributes any exhaust emissions [4].

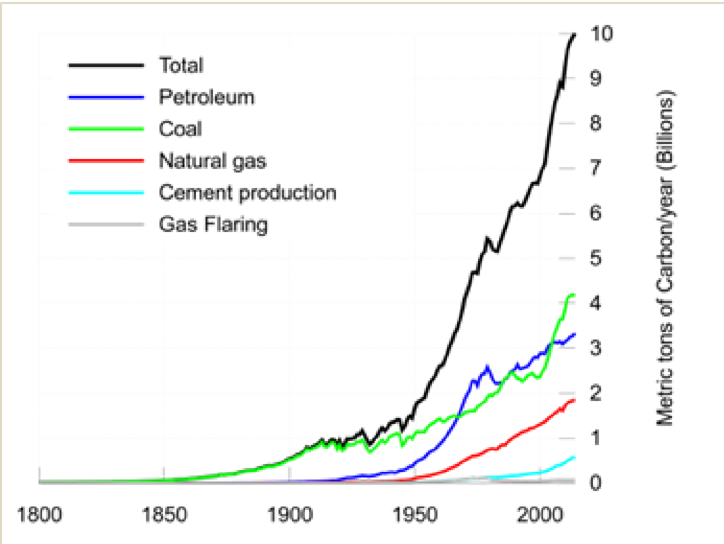

Figure 1: Carbon Emission from Combustion of Fuel [4]

A battery, an ultracap energy storage, an Insulated-Gate Bipolar Transistor (IGBT) converter and an alternate current (AC) motor equipped with an inverter is make up the electric powertrain. It is sufficient to take into account main components such as the battery, inverter, motor, and gear when comparing the three various types of AC motors [5].

A battery pack serves as the power source, a motor controller regulates speed and torque, an electric traction motor produces torque and angular velocity, and a final drive distributes the motor mechanical output to the back axle as shown in **Figure 2** so that the vehicle able to move forward. As an optional, an auxiliary circuit is used to manage any vehicle accessories. This auxiliary circuit, however is unrelated to the operation of the powerplant. The (DC) design was chosen because of its established technology, ease of setup and operation, and accessibility of relevant lightweight and small EV parts. Although the AC system has better torque and speed characteristics, it is more suitable for full-size production passenger cars [6].

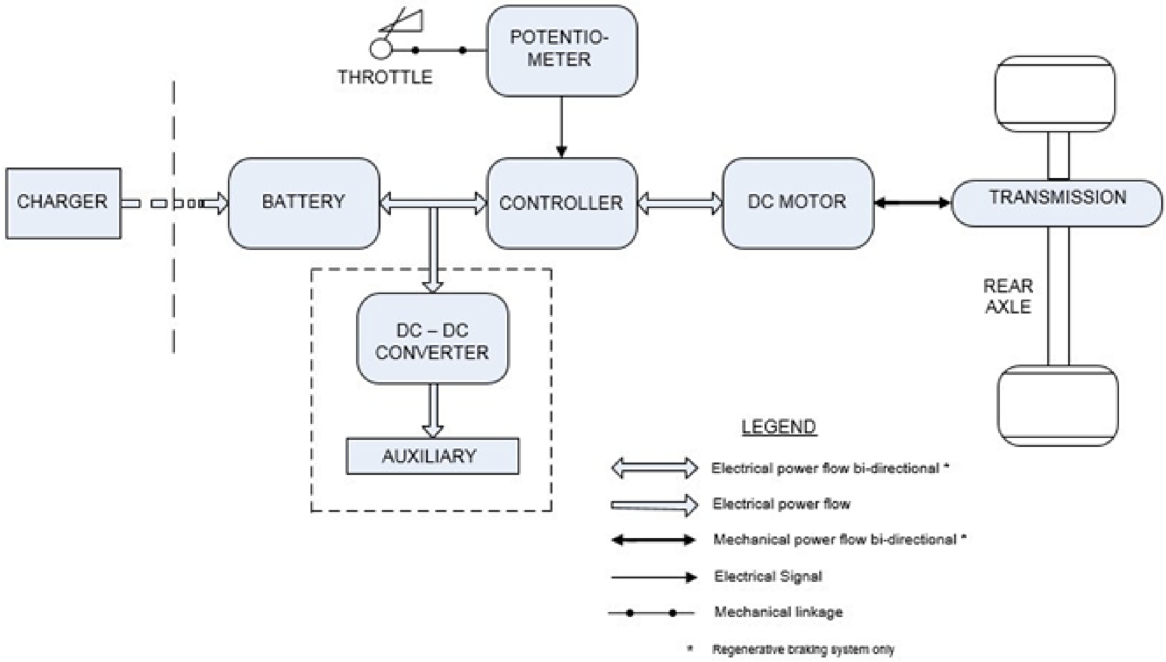

Figure 2: Electric vehicle DC drive architecture [6]

2. Methodology and Materials

Research methodology is important to ensure that the method of research used in this investigation is relevant. It is the most efficient way in gaining data to arrive to the objective of this investigation. A selection of setup are consisted of four main concepts which are components selection, 3D modelling and motion study, organization of powertrain and the prototype development.

2.1 Methodology

The development of the electric powertrain undergone a series of related approaches. Firstly, literature review is done to evaluate, compare and identify the best material and configuration for the powertrain. This includes the CAD modelling, simulation and 3D printing before the investigation is extended to the development of the powertrain and testing for performance. The flowchart as shown in **Figure 3** summarizes the overall methodology and approaches in this investigation.

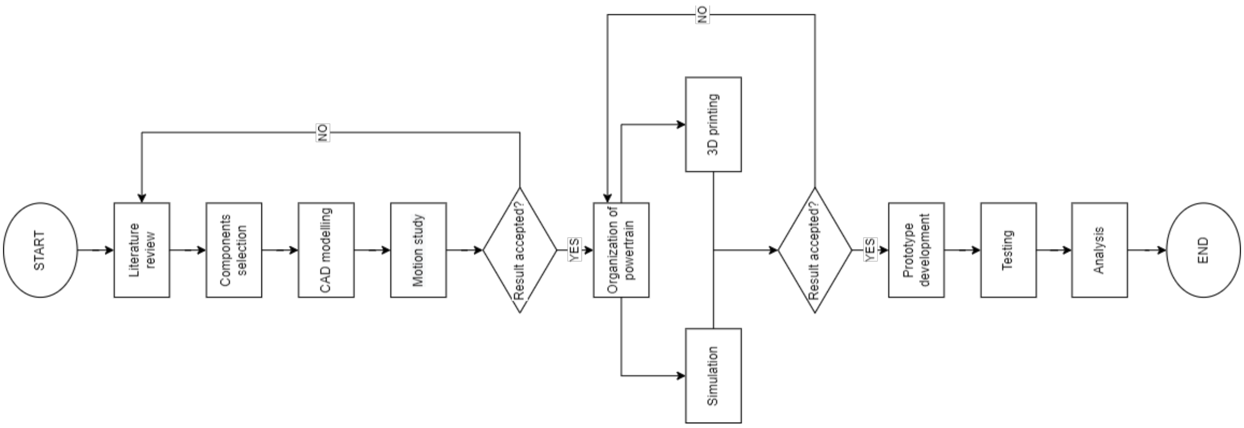

Figure 3: Methodology and extablished approaches in this investigation

2.2 Materials

In this project, the main components that make up the powertrain are batteries and motor. Several type of each component are analysed and the most suitable material is chosen based on a few implication factors such as the cost and the durability. The selected materials are for batteries, motor, battery management system (BMS) and other related components. The chosen pack of batteries are 3.2V LiFePO4 unit to store energy needed to power the motor.Total number of 16 packs of LiFePO4 batteries are combined to provide a total voltage of 51.2 V. For the motor, 48V DC2000W brushless motor is used to drive the powertrain. This includes the motor controller system, accelerator pedal and related wiring.

Table 1: Characteristics of chosen battery and motor

Components	Characteristics	Parameter
3.2V LiFePO4 Battery	Nominal voltage	3.2 V
	Charging Time	7 hours
	Discharge capacity	100 Ah
	Approximate efficiency	90 %
	Cycle life	2500 times
	Approximate weight	2700 g
	Cost per item	RM62.00
48V DC2000W Brushless Motor	Type	Brushless
	Operating voltage	48 V
	Nominal power	2000 W
	RPM	4500 rpm
	Current	42 A
	Weight	6 kg
	Size	26 cm x 25 cm x 21 cm

Table 1 shows the characteristics of chosen batteries and motor. Other than that, BMS responsibles to communicate with the motor control system of the electric go-kart. This is done by tracking the charge rate across the entire pack down to the cell level. Monitoring system assures dependable batteries are functioning, leading to the development of electric car that is safer and more effective. Lastly, a few other components are added to evaluate the performance of the powertrain in an appropriate manner. This including the accelerator pedal, battery indicator, chain, sprocket and existing go-kart chassis and components.

2.3 Related Expression for Estimation

In this investigation, Eq. (1) and (2) are used in this project to extimate the average voltage and the voltage per minute produced by the powertrain after the performance test.

$$Average\ Voltage = \frac{T_1 + T_2 + T_3}{\sum T} \qquad \textbf{Eq. 1}$$

$$Voltage\ per\ minute = \frac{Average\ Voltage}{Time} \qquad \textbf{Eq. 2}$$

3. Results and Discussions

The results obtained have been analyzed in terms of performance in actual testing and simulation. The 3D design and simulation, 3D printing and testing were adopted in order to analyze the performance of the powertrain.

3.1 Results

The results are opted through flow of method from CAD modelling and simulation, 3D printing, development and testing.

3.1.1 CAD Modelling and Simulation

The CAD model of the powertrain is designed in a smaller scale. Several designs are produced to find the most practical design. The final design of the powertrain is then simulated to ensure it works before proceeding to the next step as shown in **Figure 4**.

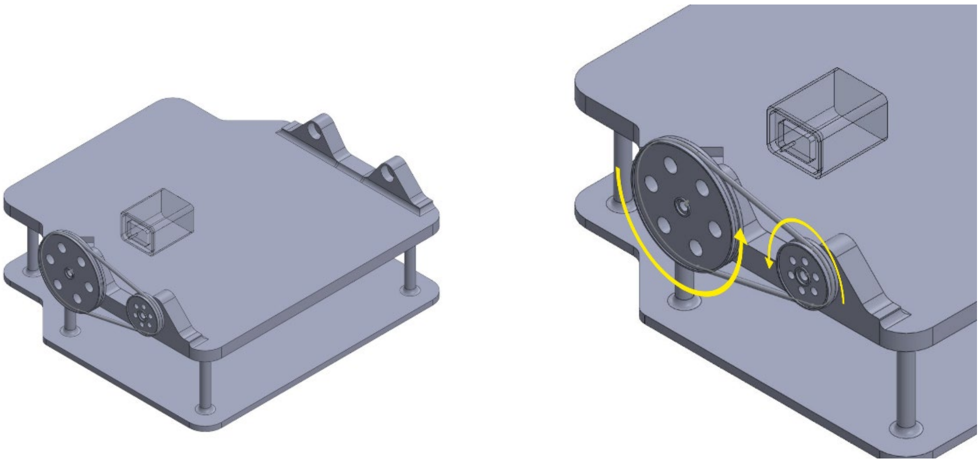

Figure 4: CAD design of the powertrain and the simulated flow of each components.

3.1.2 The 3D Printing

The CAD design of the powertrain is then converted into Standard Triangle Language (STL) file to be printed out. The name STL is an acronym that stands for stereolithography a popular 3D printing technology. The Polylactic Acid (PLA) material is chosen as its cost effective. PLA is a plant-based, biodegradable plastic. Its popularity in 3D printing stems from its incredible printability and versatility. The printed components are the base and pulleys as shown in **Figure 5**. Other components such as motor, string, bearing and steel rod were onshelf purchased. All the components were assembled together and tested. It is found that the components are suitable and working appropriately

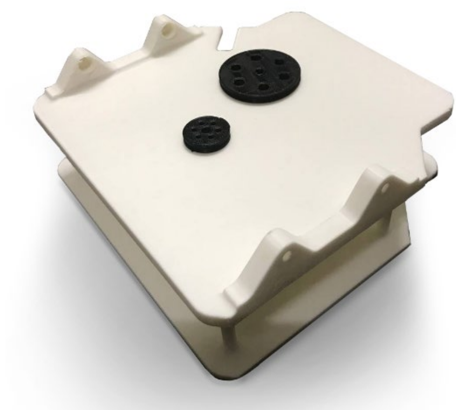

Figure 5: 3D printed components

3.1.3 Development and Testing

The result from the previous steps were used in order to preceed for the development of the powertrain. The batteries, motor, controller, BMS, chain, sprocket are assembled together and mounted into an existing go-kart chassis. The development processes are shown in **Figure 6.**

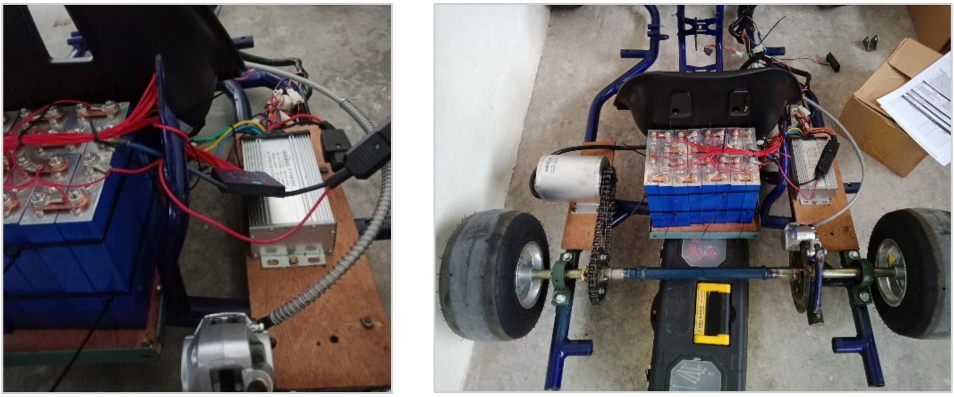

Figure 6: Assembly of the powertrain

The go-kart is then positioned on a platform to elevate the rear tyre to ensure the go-kart remains static during testing. Next, throttle is pressed into full power for 5 and 10 minutes for a several time to test the performance of the developed electric powertrain. **Table 2** shows the results of the testing.

Table 2: Results of the performance testing

Testing	Time (minutes)	Initial Voltage, V_1 (V)	Final Voltage, V_2 (V)	$V_1 - V_2$
1	5	53.6	53.3	0.3
2	5	53.3	53.1	0.2
3	5	53.1	52.8	0.3
4	10	53.8	53.2	0.6
5	10	53.2	52.7	0.5
6	10	52.7	52.2	0.5

3.2 Discussion

Figure 7 shows the result of voltage drop after series of testing. This will expose a clear behaviour and performance of the of the powertrain.

From the testing, the voltage drop is decreasing linearly. This indicates the powertrain is losing power in a constant patern with a slight tolerance. It was found that the voltage different between the initial and final voltage between 0.2V to 0.3V for every duration of 5 minutes and 0.5V to 0.6V for every duration of 10 minutes. To establish the voltage drop per minute, Eq.1 and Eq. 2 were used. For the duration of 5 minutes,

$$\frac{0.3V + 0.2V + 0.3V}{3} = 0.267V$$

$$\frac{0.267V}{5\,min} = 0.0534\,V/min$$

Thus, from this estimation, the voltage drop per minute is $0.0534V/min$. To validate this outcome, the voltage drop for the duration of 10 minutes is calculated as well using the same expression.

$$\frac{0.6V + 0.5V + 0.5V}{3} = 0.533V$$

$$\frac{0.533V}{10\,min} = 0.0533\,V/min$$

Hence, it can be concluded that the voltage drop per minute is approximately equal to $0.0533V/min$. After testing was completed, the powertrain is still in an excellence condition. There is no damage for every component and no sign of overheating was found.

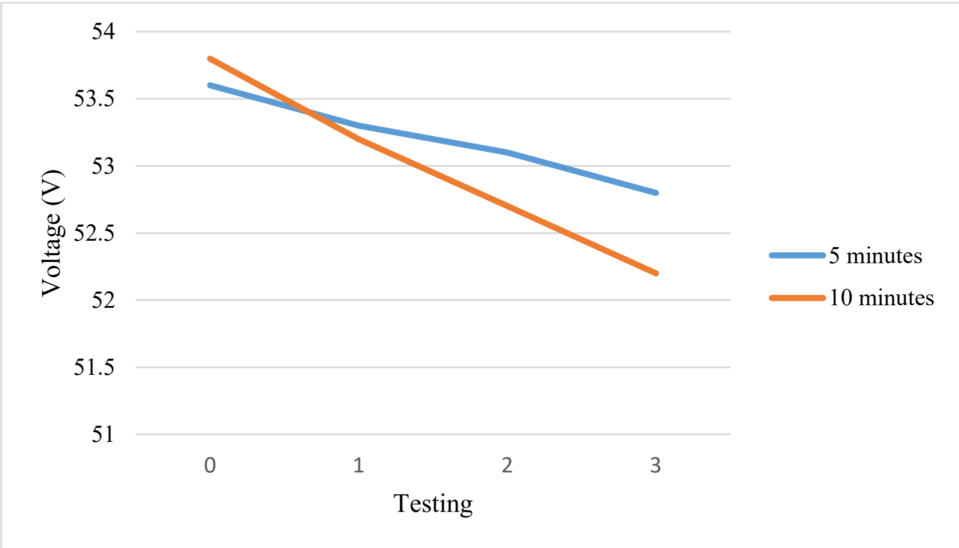

Figure 7: Voltage drop per testing

4. Conclusion

In conlusion, the powertrain which consisted of LiFePO4 batteries and DC2000W motor is working successfully and able to perform appropriately for the duration more than 30 minutes without any failure. Hence, electric motor and batteries are suitable as an alternative technology of replacing gasoline fuel. Effort to reduce carbon footprint and create environmental friendly seem significant. The objective of this investigation which is developing a powertrain of an electric go-kart using DC batteries motor is achieved. The performance of the powertrain is also tested to met the objective of this project. For future improvement, the powertrain must be tested in practical track circuit to evaluate its overall actual performance. In order to implement this testing, the go-kart chasis and mounting must be in the state of ready-to-race condition, included all other vehicle control systems such as the braking system and steering system are working perfectly. This is taken as a safety measure to ensure the driver and the testing surroundings are safe.

Acknowledgement

The authors would like to express deepest gratitude to the Centre for Diploma Studies, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] Krishnamoorthi, S., Prabhu, L., Shadan, M., Raj, H. and Akram, N., 2021. Design and analysis of electric Go-Kart. Materials Today: Proceedings, 45, pp.5997-6005.

[2] Ujwal, J., & Amin. (2021). Design of Transmission system for an Electric Go Kart. International Advanced Research Journal in Science, Engineering and Technology, 8(5). Retrieved from https://doi.org/10.17148/IARJSET.2021.85114

[3] Oak Ridge National Laboratory. (2018). Global, Regional, and National Fossil-Fuel CO2 Emissions. Lbl.gov. Retrieved from https://cdiac.ess-dive.lbl.gov/trends/emis/overview.html

[4] US EPA. (2016, January 12). Greenhouse Gas Emissions from a Typical Passenger Vehicle. US EPA; United States Environmental Protection Agency. Retrieved from https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle#:~:text=typical%20passenger%20vehicle%3F-

[5] Neudorfer, Harald. (2007). Comparison of three different electric powertrains for the use in high performance Electric Go-Kart. 21 - 26. 10.1109/ACEMP.2007.4510478.

[6] Burridge, M., & Alahakoon, S. (2017). The Design and Construction of a Battery Electric Vehicle Propulsion System - High Performance Electric Kart Application. IOP Conference Series: Earth and Environmental Science, 73, 012016.