



Optimizing Performance of a 4 kW BLDC Motor in Go-Kart Through Load and Speed Testing

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Abstract: The development of electric go-karts involves overcoming challenges related to efficiency across different driving conditions. A key issue is the reduction in efficiency caused by changes in speed and the driver's weight, both of which impact the motor's power demands. This study focuses on examining how variations in driver weight (55 kg, 65 kg, and 75 kg) and speed (40 km/h, 50 km/h, and 60 km/h) affect the efficiency of a 4 kW BLDC motor in an electric go-kart. The research employed a quantitative experimental approach, conducting field tests on a 300-meter flat track. Key data, including voltage, current, and torque, were measured to calculate the motor's input and output power, with efficiency determined by the power ratio formula. Analysis using a Two-Way ANOVA test revealed that both driver weight and speed, as well as their interaction, had a significant effect on efficiency ($p < 0.001$). The highest efficiency recorded was 95.45% at 55 kg and 40 km/h, while the lowest was 62.49% at 75 kg and 60 km/h. These findings align with previous research, confirming that increased load and speed decrease efficiency. Such insights can guide strategies to optimize electric vehicle performance.

Keywords: efficiency; performance; power; consumption; torque



SDGs Problem Solving

Research and problem-solving approaches directly support the SDGs by fostering innovation, data-driven solutions, and evidence-based decision-making. In the context of optimizing electric go-kart efficiency, systematic experimentation and analysis contribute to SDGs Chapter #7 targets related to clean energy, sustainable transportation, and responsible consumption, promoting environmentally friendly technological advancements.

Conflict of Interest Statement: The author(s) declares that the research was conducted in the absence of any commercial or financial relationship that could be construed as a potential conflict of interest.

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1. INTRODUCTION

Electric vehicles have become one of the most significant innovations in the modern automotive industry, offering numerous advantages over conventional fossil fuel-powered vehicles, particularly in terms of energy efficiency and environmental impact ([Ferlia, Sudarti and Yushardi, 2024](#)). Compared to fossil fuel-based engines, electric motors are able to generate high torque from the start of the car's movement, giving it better acceleration and performance than internal combustion engine-based cars ([Hendra, Yadie and Arbain, 2021](#)). In their development, electric go-karts are now beginning to emerge as an attractive alternative in the world of entertainment and racing, replacing gasoline-powered go-karts. These vehicles combine high torque, compact design, and zero emissions, aligning with growing environmental awareness and technological advancements in motorsport ([Chandramohan et al., 2021](#); [Aswar et al., 2022](#)).

One of the main components that determine the performance of electric vehicles is the Brushless Direct Current (BLDC) motor. This motor is known for its high efficiency, compact design, and reliability in various electric mobility applications. BLDC motors have the ability to generate high torque at low speeds, precise electronic control, and optimal energy efficiency ([Ma'arif et al., 2022](#)). Incorrect settings on BLDC motor drivers or controllers can reduce performance efficiency, as indicated by symptoms such as overheating, reduced power output, or excessive power consumption, resulting in wasted electrical energy ([Putro and Ma'arif, 2024](#)).

Previous research on the efficiency of BLDC motors in electric vehicles has mostly focused on electric motorcycles and cars. Mahendra et al. analyzed the efficiency of a 500 W BLDC motor in an electric motorcycle prototype. The tests covered torque, power, voltage, current, and rotational speed. The results showed that a 90 kg load reduced speed by 11.72% from 27.3 KPH to 24.1 KPH, torque decreased by 20.94% from 5.97 N.m to 4.72 N.m, and power decreased by 19.67% from 0.488 Hp to 0.392 Hp. Battery voltage also decreased by 1.85% from 48.8 V to 47.9 V. These findings indicate that load significantly affects motor performance, particularly in terms of torque and power consumption ([Mahendra, Fatra and Tamamudin, 2024](#)).

Ikhsan et al. analyzed the power and battery capacity used to drive electric motorcycles with varying driver weights (60 kg, 90 kg, 125 kg) and speeds (10 km/h, 20 km/h, 30 km/h, 38 km/h). The results showed that increases in weight and speed led to increased power consumption and battery capacity, which impacted battery efficiency and reduced its durability ([Ikhsan et al., 2022](#)).

Real load analysis on small-scale electric vehicles has also been conducted by several researchers. Garniwa et al. studied the effect of load variations on BLDC performance in KARLING electric vehicles and reported that load changes affect torque output and speed, which ultimately reduces drive system efficiency if not balanced by appropriate control strategies or designs. These findings reinforce the need for field testing on real vehicle platforms to capture the operating behavior of BLDCs under real conditions ([Garniwa et al., 2019](#)).

Gupta and Varshney analyzed the speed–torque characteristics of BLDC motors under various load conditions (under-load, rated, overload) and reported significant changes in speed response as the load increased, confirming that load variations directly affect motor operating parameters such as speed and torque ([Gupta and Varshney, 2020](#)).

Mara et al. conducted an experimental study on electric vehicles with loads of up to 960 kg and varying speeds, finding that the lowest energy consumption was achieved at a speed of 20 km/h, while a speed of 40 km/h caused a decrease in efficiency, especially at high loads (Mara et al., 2025). This research supports the finding that increased load and speed have a negative impact on the efficiency of electric vehicles and reinforces the argument for the need for specific testing on motors and light electric vehicles such as go-karts.

Expanding on this, Amartyasen et al. investigated BLDC motor efficiency in electric scooters under urban driving conditions, reporting efficiency drops of up to 15% with payload increases, emphasizing the role of regenerative braking in mitigating losses (Amartyasen, Balaji and Vigneshwar, 2025). In a related study, Ristiana et al. optimized BLDC motor controllers for electric motorcycles, achieving a 12% efficiency improvement through advanced PWM techniques, with tests showing reduced heat dissipation at high speeds (Ristiana et al., 2022). For electric cars, Patel et al. analyzed BLDC motor performance in lightweight EVs, noting that motor efficiency peaked at 85-90% under optimal torque-speed curves, but declined with aerodynamic drag at speeds over 60 km/h (Patel, Yadav and Tiwari, 2024).

However, studies specifically addressing the performance of BLDC motors in electric go-karts are still very limited, even though go-karts have unique characteristics in terms of load, power, and design. With a simpler structure, go-karts are designed to provide high stability and fast acceleration (Malla et al., 2025).

Based on these gaps, this study aims to analyze the effect of driver weight variation and speed variation on the efficiency of a 4 kW BLDC motor in an electric go-kart designed by the Automotive Racing Team of the University of Jakarta. Focusing on this specific application is expected to provide practical contributions to efforts to optimize performance and energy efficiency in small-scale racing vehicles.

2. METHODOLOGY

In this study, the research and analysis process was divided into several stages, as shown in Figure 1. The process began with a literature study, in which various previous studies and theories related to BLDC motors, electric go-karts, and energy efficiency were examined to establish the basis for discussion in this study. Next, testing preparations were made by preparing the equipment and materials. Data collection was conducted through field tests with variations in driver weight and speed, where parameters such as voltage, current, and power were measured. After that, the obtained data was calculated to determine the input power, output power, and motor efficiency, then statistically analyzed to see the effect of load and speed variations on motor performance.

The research approach used in this study is a quantitative approach with an experimental method. Sugiyono states that the experimental method is a quantitative approach used to determine the impact of independent variables on dependent in a controlled situation (Sugiyono, 2011). The research instrument used in this study is data collection in the form of measurements in testing the designed tool. The results were analyzed to determine the influence of driver load and speed on the efficiency of the BLDC motor in electric go-karts. Several variables in this study included variations in driver load values, namely 55 kg, 65 kg, and 75 kg. The variations in the speed of the electric go-kart

were 40 km/h, 50 km/h, and 60 km/h. The tests were conducted with the electric go-kart according to the plan on a predetermined track. The track used in this study was located at Campus A of the State University of Jakarta on a flat and straight terrain with a track length of 300 meters. The measurement data were recorded using measuring instruments and analyzed statistically using a two-way ANOVA method to examine the effects and interactions between the variables of driver weight and speed on the efficiency of the BLDC motor (Rahmawati and Erina, 2020).

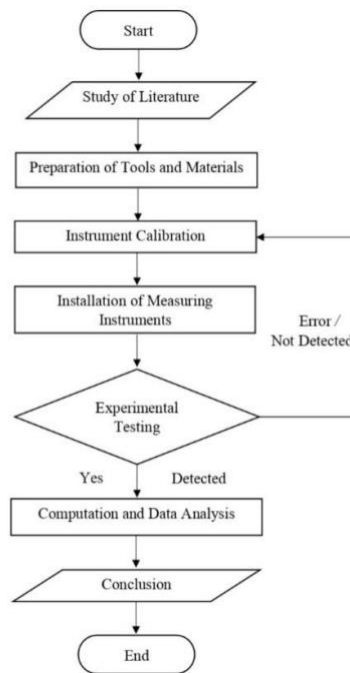


Figure 1. Research flowchart

In the design of this device, a battery with a capacity of 72 V 20 Ah is used as the power source to drive a brushless DC motor with a power of 4 kW. The electrical current from the battery enters the MCB as a safety component in case of current leakage and electrical damage. After passing through the MCB, the current goes to the controller to regulate the rotation of the brushless DC motor as the drive for the electric motorcycle. The ignition switch serves as a switch to turn the controller on and off. When turning it on, the ignition switch is positioned to ON, causing the controller to function. When turning it off, the ignition switch is positioned to OFF, causing the controller to shut down and cease functioning, thereby also stopping the brushless DC motor. The throttle potentiometer is used to adjust the rotational speed of the brushless DC motor. The brushless DC motor, which serves as the drive for the electric go-kart, is connected to the gear via a chain. Figure 2 shows the electrical schematic for this study.

2.1. Electric Go-Kart

Gokarts are four-wheeled vehicles that are similar in structure to cars. These vehicles are generally used for entertainment and racing, just like Formula 1 racing (see Figure 3). Smaller in size when compared to other types of four-wheeled vehicles, Gokarts are equipped with smaller capacity engines. This vehicle can be used in various places, such as fields, to official racing circuits (Kanda and Hamidah, 2024).

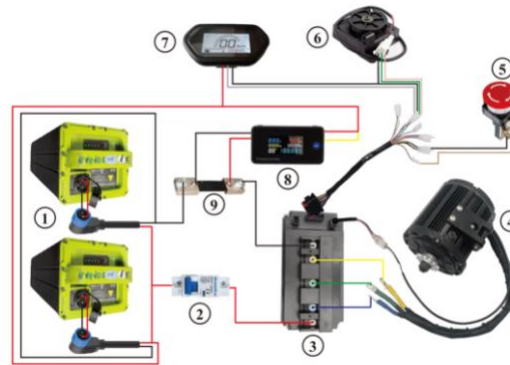


Figure 2. Electric go-kart wiring diagram



Figure 3. Electric go-kart

Electric go-karts are go-karts that have been converted from gasoline-powered to electric-powered vehicles. These electric vehicles use Lithium-Ion batteries with a voltage of 72 V/20 Ah, Votol EM150/180 A/4 kW controllers, and are equipped with Brushless DC (BLDC) motors.

2.2. Efficiency

Electric motor efficiency is a parameter that measures the motor's ability to convert the given electrical energy into mechanical energy efficiently by minimizing energy loss. Efficiency is the ratio between output power and input power, expressed as a percentage. The efficiency value is very important because it reflects how effective the motor is in converting electrical energy into mechanical work without much wasted energy, such as in the form of heat or other losses (Diantoro, 2024).

The following are the formulas used in calculating efficiency, input power, output power, angular velocity, torque, force, and acceleration during the experiment:

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% \quad (1)$$

where η is efficiency (%); P_{out} is output power (Watt); and P_{in} is input power (Watt).

$$P_{in} = \sqrt{3} \times V \times I \times \cos \varphi \quad (2)$$

where P_{in} is input power (Watt); V is voltage (volt); I is current (ampere); and $\cos \varphi$ = power factor.

$$P_{\text{out}} = \omega \times T \quad (3)$$

where P_{out} is output power (Watt); ω is angular velocity (rad/s); T is torque (Nm).

$$\omega = \frac{v}{r} \quad (4)$$

where ω is angular velocity (rad/s); v is velocity (m/s); and r is radius of shaft or wheel (m).

$$T = F \times s \quad (5)$$

where T is torque (Nm); F is force (N); and s is Perpendicular distance from pivot to force (m).

$$F = \frac{m \cdot a}{2} \quad (6)$$

where F is force (N); m is mass (kg); and a is acceleration (m/s^2).

$$a = \frac{v - v_0}{t} \quad (7)$$

where a is acceleration (m/s^2); v is final velocity (m/s); v_0 is initial velocity (m/s); and t is time (s).

3. RESULTS AND DISCUSSION

After testing with driver weights of 55 kg, 65 kg, and 75 kg at speeds of 40 km/h, 50 km/h, and 60 km/h, measurements of voltage, current, and power were taken three times. The average of each data point was then calculated. Detailed results are presented in [Table 1](#), [Table 2](#), and [Table 3](#).

Table 1. Test results data for a driver weight of 55 kg with variations in speed

No	Load (kg)	Speed (km/h)	Voltage (V)	Current (A)	Power (W)
1.	55	40	81.2	19.6	1.598
			80.4	21.7	1.752
			80.0	19.9	1.593
2.	55	50	78.8	27.5	2.174
			80.6	27.3	2.207
			80.3	26.6	2.138
3.	55	60	79.1	32.7	2.594
			79.5	30.4	2.420
			79.2	31.9	2.529

Table 2. Test results data for a driver weight of 65 kg with variations in speed

No	Load (kg)	Speed (km/h)	Voltage (V)	Current (A)	Power (W)
1.	65	40	80.9	25.3	2.053
			80.1	25.5	2.048
			80.5	25.5	2.056
2.	65	50	79.5	28.2	2.250
			79.8	28.0	2.236
			79.6	29.8	2.375
3.	65	60	79.9	32.2	2.579
			80.4	32.4	2.605
			79.5	33.3	2.655

Table 3. Test results data for a driver weight of 75 kg with variations in speed

No	Load (kg)	Speed (km/h)	Voltage (V)	Current (A)	Power (W)
1.	75	40	80.7	28.8	2.325
			80.4	28.9	2.325
			81.1	29.5	2.396
2.	75	50	79.7	35.2	2.811
			79.0	35.4	2.806
			78.7	35.6	2.808
3.	75	60	79.9	40.9	3.277
			80.3	40.6	3.267
			79.8	40.8	3.264

After obtaining the research data, calculations and analyses were performed using the previous formula to determine the efficiency of the BLDC motor at each load and speed. After the calculation process is done, next is presenting the motor efficiency data obtained from comparing the output power and input power. The calculation results by using equation (1) – (7) can be seen in [Table 4](#), [Table 6](#), and [Table 8](#). The average calculation results can be seen in [Table 5](#), [Table 7](#), and [Table 9](#).

Table 4. Calculation results for a driver weight of 55 kg with variations in speed

No	Load (kg)	Speed (km/h)	P _{Input} (W)	P _{Output} (W)	Efficiency (%)
1.	55	40	992.37	948.60	95.58
			1,087.87	1,051.15	96.62
			992.67	948.60	94.16
2.	55	50	1,351.20	1,131.65	83.75
			1,372.02	1,131.65	82.48
			1,331.86	1,056.92	79.35
3.	55	60	1,612.82	1,332.76	82.63
			1,506.96	1,178.98	78.23
			1,575.35	1,332.76	84.60

Table 5. Average calculation results for a driver weight of 55 kg

No	Load (kg)	Speed (km/h)	P _{Input} (W)	P _{Output} (W)	Efficiency (%)
1.	55	40	1,024.30	982.78	95.45
2.	55	50	1,351.69	1,106.74	81.86
3.	55	60	1,565.04	1,281.50	81.82

Table 6. Calculation results for a driver weight of 65 kg with variations in speed

No	Load (kg)	Speed (km/h)	P _{Input} (W)	P _{Output} (W)	Efficiency (%)
1.	65	40	1,276.23	1,010.13	79.14
			1,273.60	1,010.13	79.31
			1,279.96	1,010.13	78.91
2.	65	50	1,397.91	1,125.25	80.49
			1,393.23	1,125.25	80.76
			1,479.08	1,205.32	81.49
3.	65	60	1,604.22	1,255.87	78.28
			1,624.29	1,255.87	77.31
			1,650.72	1,186.66	71.88

Table 7. Average calculation results for a driver weight of 65 kg

No	Load (kg)	Speed (km/h)	P _{Input} (W)	P _{Output} (W)	Efficiency (%)
1.	65	40	1,276.59	1,010.13	79.12
2.	65	50	1,423.40	1,151.94	80.91
3.	65	60	1,626.41	1,232.80	75.82

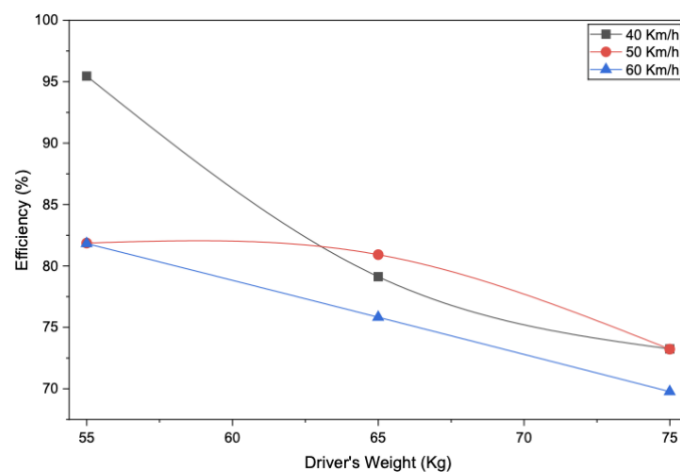
Table 8. Calculation results for a driver weight of 75 kg with variations in speed

No	Load (kg)	Speed (km/h)	P _{Input} (W)	P _{Output} (W)	Efficiency (%)
1.	75	40	1,449.20	1,071.66	73.94
			1,448.82	1,071.66	73.96
			1,491.78	1,071.66	71.83
2.	75	50	1,749.29	1,278.98	73.11
			1,743.78	1,278.98	73.34
			1,746.97	1,278.98	73.21
3.	75	60	2,037.66	1,418.62	69.62
			2,032.84	1,418.62	69.78
			2,030.14	1,418.62	69.87

Table 9. Average calculation results for a driver weight of 75 kg

No	Load (kg)	Speed (km/h)	P _{Input} (W)	P _{Output} (W)	Efficiency (%)
1.	75	40	1,463.26	1,071.66	73.24
2.	75	50	1,746.68	1,278.98	73.22
3.	75	60	2,033.54	1,418.62	69.76

Figure 4 shows that the highest efficiency of the BLDC motor occurs at a driver load of 55 kg and a speed of 40 km/h, which is 95.45%. At the same load and a speed of 50 km/h, the efficiency decreases to 81.86% and decreases slightly again at a speed of 60 km/h to 81.82%. At a load of 65 kg, the highest efficiency is achieved at a speed of 50 km/h, at 80.91%, then at a speed of 40 km/h, efficiency decreases to 79.12%, and at a speed of 60 km/h, it becomes 75.82%. Meanwhile, at the heaviest load of 75 kg, efficiency continues to decrease with increasing speed, with values of 73.24% at 40 km/h, 73.22% at 50 km/h, and the lowest at 69.76% at 60 km/h.

**Figure 4.** Graph of average efficiency of BLDC motors

To analyze the relationship between independent and dependent variables in this study, a statistical method in the form of a two-way analysis of variance (Two-Way ANOVA) was used. This test aims to determine whether there is a significant effect of each independent variable independently (main effect), as well as whether there is a combined or interactive effect (interaction effect) between the two independent variables on the dependent variable (Heumann, Schomaker and Shalabh, 2023).

Before testing the hypothesis using Two-Way ANOVA, a classical assumption test was first conducted to ensure that the data used met the requirements for parametric statistical analysis. This classical assumption test included a normality test and a homogeneity of variance test, which aimed to ensure the validity of the analysis results. The normality test in this study aims to test whether the data used has a normal distribution or not. In this study, normality testing was carried out using the Kolmogorov-Smirnov method with IBM SPSS Statistics 30.0 software. The results of the normality test in this study can be seen in Figure 5.

One-Sample Kolmogorov-Smirnov Test		
		Unstandardized Residual
N		27
Normal Parameters ^{a, b}	Mean	.0000000
	Std. Deviation	2.23110512
Most Extreme Differences	Absolute	.186
	Positive	.121
	Negative	-.186
Kolmogorov-Smirnov Z		.964
Asymp. Sig. (2-tailed)		.311

a. Test distribution is Normal.
b. Calculated from data.

Figure 5. Results of normality test

Based on Figure 5, the results of the normality test using the One Sample Kolmogorov-Smirnov Test show that the significance value is $0.311 > 0.05$, so it can be concluded that the data is normally distributed.

Homogeneity test is conducted to determine whether two or more groups of data have the same variance or not. Data is said to be homogeneous if the α value > 0.05 . Conversely, if the α value < 0.05 then the data is declared inhomogeneous. In this study, the homogeneity test was conducted using the Levene's Test method with IBM SPSS Statistics 30.0 software. The results of homogeneity testing can be seen in Figure 6.

Test of Homogeneity of Variances			
hom			
Levene Statistic	df1	df2	Sig.
2.121	2	23	.143

Figure 6. Results of homogeneity test

Based on Figure 6, the results of the homogeneity test using Levene's Test show that the significance value is $0.143 > 0.05$, so it can be concluded that the data has a homogeneous variance. This means that the assumption of homogeneity of variance between groups is met, and the data is suitable for analysis using the ANOVA test.

Interpretation of the two-way ANOVA test results is done by looking at the significance value (Sig.). If the α value > 0.05 , it is concluded that there is no significant effect. Conversely, if the α value < 0.05 , then there is a significant influence between the variables tested. In this study, hypothesis testing was carried out using IBM SPSS Statistics 30.0 software. The results of hypothesis testing can be seen in Figure 7.

Tests of Between-Subjects Effects

Dependent Variable: Efisiensi

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.038 ^a	8	.005	45.388	<.001
Intercept	97.061	1	97.061	924121.190	<.001
Berat_Beban	.027	2	.014	128.606	<.001
Kecepatan	.006	2	.003	27.329	<.001
Berat_Beban * Kecepatan	.005	4	.001	12.808	<.001
Error	.002	18	.000		
Total	97.101	27			
Corrected Total	.040	26			

a. R Squared = .953 (Adjusted R Squared = .932)

Figure 7. Result of hypothesis test using two-way ANOVA test

Based on Figure 7, the following conclusions can be drawn:

- 1) Based on the calculation results through the two-way ANOVA test, at a significance level of 5% (0.05), a significance value of $< 0.001 < 0.05$ is obtained, so H_0 is rejected and H_1 is accepted. So, it can be concluded that there is a difference in the average value of BLDC motor efficiency on electric go-karts based on variations in driver weight. This means that the weight of the driver's load has a significant influence on the efficiency of the BLDC motor on electric go-karts.
- 2) Based on the calculation results through the two-way ANOVA test, at a significance level of 5% (0.05), a significance value of $< 0.001 < 0.05$ is obtained, so H_0 is rejected and H_1 is accepted. So, it can be concluded that there is a difference in the average value of BLDC motor efficiency on electric go-karts based on speed variations. This means that speed has a significant influence on the efficiency of BLDC motors on electric go-karts.
- 3) Based on the calculation results through the two-way ANOVA test, at a significance level of 5% (0.05), a significance value of $< 0.001 < 0.05$ is obtained, so H_0 is rejected and H_1 is accepted. So, it can be concluded that there is an interaction effect between variations in driver weight and speed variations on the efficiency of BLDC motors in electric go-karts.

The results of this study are in line with the research of Varshney & Dwivedi and Gupta & Varshney which explains that additional mechanical loads will increase current consumption and reduce BLDC motor efficiency. Thus, the driver's body weight is one of the important factors that affect motor efficiency in electric go-karts (Varshney and Dwivedi, 2016; Gupta and Varshney, 2020).

This result is also in line with the findings of Agrawal et al., who explained that motor efficiency is highly dependent on the interaction between speed and load. An imbalance between the two will increase energy consumption and reduce system performance. Therefore, this interaction must be considered in the design of electric vehicle control systems so that efficiency can be maintained under dynamic conditions (Agrawal et al., 2025).

From the test results, it can be concluded that the efficiency of the BLDC motor tends to decrease with increasing driver load and vehicle speed. The highest efficiency is achieved under conditions of light load and low speed, while the lowest efficiency occurs under the combination of heavy load and high speed. This shows that BLDC motors work more optimally under conditions of light load and medium to low speed.

The findings indicate that the efficiency of the BLDC motor decreases with increased driver weight and vehicle speed. To minimize this effect, future studies could apply an adaptive control system that adjusts current and torque according to real-time load conditions. This approach often referred to as load-compensated torque control can maintain optimal motor performance while reducing energy losses. Furthermore, optimization of gear ratios and battery management strategies can also improve energy efficiency, especially in lightweight electric racing vehicles such as go-karts.

4. CONCLUSION

This study analyzes the effect of driver weight variation (55 kg, 65 kg, 75 kg) and speed variation (40 km/h, 50 km/h, 60 km/h) on the efficiency of a 4 kW Brushless DC (BLDC) motor in an electric go-kart. The test results show that increasing weight and speed causes a significant decrease in motor efficiency. The highest efficiency of 95.45% was obtained at a load weight of 55 kg with a speed of 40 km/h, while the lowest efficiency of 69.76% occurred at a load of 75 kg and a speed of 60 km/h. Based on the results of statistical tests using two-way ANOVA, it was found that driver weight and speed had a significant influence on motor efficiency ($<0,001 < 0.05$), and there was a significant interaction between the two variables.

This study concludes that although the 4 kW BLDC motor exhibits high efficiency at light load and medium speed, its performance degrades significantly as load and speed increase. Therefore, further development in load management and motor control strategies is needed to optimize energy efficiency in electric go-karts and other electric vehicles.

Future research should focus on developing adaptive load control or torque compensation methods to reduce the negative impact of driver weight on efficiency, thereby enhancing the performance and energy sustainability of electric go-karts.

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