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Design and Development of Electrical Go Kart

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***Abstract* – This study explores the complex process of designing, developing, and building an electric go-kart with a focus on performance and sustainability. Using a multidisciplinary methodology, the research maximizes the vehicle's efficiency and environmental friendliness by integrating the principles of mechanical engineering, electrical engineering, and sustainable design. The study assesses many design factors, including motor power, battery capacity, and chassis materials, to find an ideal balance between performance and environmental impact through methodical experimentation and analysis. To improve the kart's energy economy and agility, the project also investigates cutting-edge technologies including lightweight composite materials. The results of this study offer significant contributions to the subject of sustainable transportation, as well as to the development of electric car technology. Through the demonstration of the viability and efficiency of electric go-karts in comparison to their conventional gasoline-powered equivalents, this study highlights the significance of adopting renewable energy solutions within the automotive sector. In the end, the journal clarifies how electric go-karts can transform both competitive and recreational racing, making a strong argument for the broad use of clean energy technology in the quest for a more sustainable and environmentally friendly future.**

Keywords—Electric Go Kart, Sustainable Transportation, Lightweight Composite Materials, Renewable Energy Solutions.

I. Introduction

The development and use of electric cars (EVs) as a sustainable substitute for traditional gasoline-powered vehicles has significantly increased in recent years [1]. This pattern is not limited to the car industry; it is also noticeable in the sports and leisure industries. Among these, electric go karts have become a popular and green choice for both pros and enthusiasts.

Compared to their conventional gasoline-powered cousins, electric go karts provide a number of benefits [2]. They are perfect for indoor racetracks, outdoor circuits, and even residential use because they are quieter, emit no emissions, and require less upkeep. With the advance of eclectic powertrain and battery technologies, the EV has evolved to the point that they accelerate faster and achieve higher efficiency in energy utilization for vehicle transportation [3].

After the increasing adoption of electric Go Karts within the competitive and recreational sectors, it has highlighted the advancements and innovations that this review aims to explore [4]. Despite the technological progress in electric vehicles, comprehensive syntheses focusing on Go Karts remain sparse. This review intends to fill this gap by providing an in-depth analysis of emerging technologies in electric Go Kart design, particularly emphasizing sustainable practices and advanced electronic systems. By focusing on cutting-edge materials for chassis construction and the latest

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developments in steering and power systems, this paper presents a critical evaluation of the innovations that enhance the performance and safety of electric Go Karts. These contributions are critical for understanding the current landscape and future potential of electric Go Karts, setting the stage for further innovation and adoption in this burgeoning field. The objectives encompass achieving efficiency, performance, and safety in the electric propulsion system while innovating in the design aspects. Additionally, the development of a cutting-edge steering system requires addressing issues related to precision control, user interface, and integration with the overall electric Go Kart design. The paper aims to review the boundaries of electric Go Kart technology by seamlessly merging design optimization with the implementation of an advanced steering system to enhance overall performance and user experience. This paper shall achieve the following goals.

- Make a reasonable trade-off among different factors and optimize the implementation of an Electric Go-Kart
- Compare different advanced steering technologies and select an approach for further improvement.

The paper is organized as follows: Section II describes the related work of electric go-kart components. Section III describes an overview of the structural work of go-kart, electric work and power transmission system. Section IV presents data comparison of battery, motor and motor controller and Section V presents conclusion, and future work of review study.

II. Literature Review

The electric go-kart has gone through a few growth stages. In the early years of 1970s to 1990s, it was invented as a novelty item instead of a serious racing machine initially, gradually maturing in the 1990s due to the emergence of powerful electric motors and advanced battery technology. It was the market expansion stage during the 2000s and 2010s. Electric go-karts gained popularity as a serious racing machine and were accepted by the major karting organizations leading to a significant adoption of E-Go-Kart for racing events [5]. Up to now, the electric Go-Kart is a competitive alternative to the gas-powered go kart and it will continue to grow to be a prominent equipment in kart racing for the continued innovation and improvement in the battery technologies and electric powertrain.

Gupta et al. has shown the importance of advanced technologies such as Brushless DC motors, motor controllers, and robust batteries [6]. They also addressed challenges such as overheating of motor regulators. Moreover, the design and optimization of an electric go-kart were usually focused on sustainability and performance.

Mateja has shown the development of a power supply system for electric go-karts using Model-Based Design [7]. The battery used in the electric go-kart is Li-Ion. He also discussed the performance, safety, and cost-effectiveness in battery system design. These three aspects should be balanced for the electric go-kart.

Ujwal Amin has shown the importance of designing a transmission system tailored for electric go-karts [8]. He addressed the requirements of the transmission system in electric go-karts. It is different from traditional go-karts due to the replacement of an engine with a battery and motor.

III. Methodology

There are three main parts for methodology which are structural work [9], electrical work [10] and power transmission system [8]. All the requirements will be in these three only.

A. Structural Work

Computer-aided design (CAD) is used to create a design simulations of real-world goods and products in 2D or 3D with scale, precision, and physics properties [11]. This is to optimize and perfect the design before manufacturing. Example, SOLIDWORKS can be used to design go kart chassis and to be build up with all the safety measures [12].

Figure 1 shows the Go Kart model is a conceptual design model to be built up [9]. Strength and light weight are the basic considerations for choosing the chassis material [13]. AISI 1018 is the suitable material to be used for the go-kart chassis which is a medium carbon steel having high tensile strength, high machinability and offers good balance of toughness and ductility.

Based on Table 1, it refers to some materials that suit the Go Kart chassis in the way to better. By that, the chassis of the Electric Go Kart can be built.

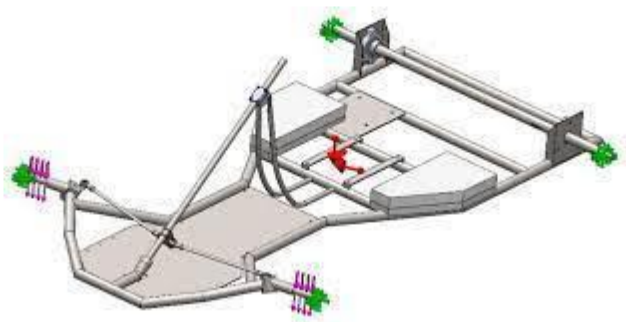

FIGURE 1. Conceptual Design model

TABLE 1. Material list

Material	Cross Section	Young's Modulus	Moment of Inertia	Bending Stiffness
AISI 1018	1" x 2mm	205 GPa	10136.74 mm^4	2078.03 Nm^2
AISI 1018	1" x 1.5mm	205 GPa	8073.32 mm^4	1655.03 Nm^2
AISI 4130	1" x 1.5mm	210 GPa	8073.32 mm^4	1695.39 Nm^2
ASTM A106 Grade B	1" x 1.5mm	192 GPa	8073.32 mm^4	1550.07 Nm^2

Finite Element Analysis (FEA) is used to evaluate the structural integrity and performance of the chassis under various load conditions [14]. The analysis involves creating a digital model of the chassis and subjecting it to simulated forces and stresses. Applied loads include the weight of the driver, acceleration forces, impact loads, and cornering forces. The goal is to ensure that the chassis can withstand these loads without excessive deformation or failure. The structural work also required some safety features. The go-kart is equipped with a roll cage made from high-strength steel tubing. The roll cage provides protection to the driver in the event of a rollover or collision, ensuring compliance with safety standards. The front and rear bumpers are designed to absorb impact energy, reducing the forces transmitted to the chassis and the driver. These bumpers are made from energy-absorbing materials that deform under impact, dissipating energy effectively. The driver's seat and controls are ergonomically designed to provide comfort and control during operation. The seat is adjustable to accommodate drivers of different sizes, and the controls are positioned for easy access and operation.

The chassis design and material selection are the core to the overall performance and safety. Go Karts typically employ a range of dimensions tailored to various racing classes, with lengths varying from 1.8 to 2.2 meters and widths around 1.2 meters, ensuring agility and stability on the track. The critical aspect is the selection of the material for chassis construction. While steel is commonly used due to cost efficiency and durability. However, lightweight materials such as aluminum and carbon fiber have become the choice of the chassis design because the weight of chassis can be reduced, improving the acceleration and handling. Moreover, the thickness of these materials can vary based on the stiffness and the level of protection needed. AISI 4130 steel tubing is commonly found in competition-level karts with wall thicknesses around 2mm. This is because of its excellent strength-to-weight ratio. The integration of these specifications into the structural design not only maximizes performance but also aim for safety standards for both recreational and competitive use

B. Electrical Work

The lifespan of electric go-karts varies based on battery type and usage. Models with lead-acid batteries typically offer 20-30 minutes of drive time per charge, while those with lithium batteries can last up to 2 hours [15]. The battery is the fundamental component that powers an electric go-kart. In addition to providing the kart with electricity, the battery is a major factor in determining how long it will last. The majority of electric go-karts have lead-acid, lithium-ion, or lithium-polymer batteries installed. Although lead-acid batteries are less expensive, lithium-ion and lithium-polymer batteries have superior performance and a longer lifespan.

Table 2 shows comparison on battery types with many factors. Thus, electric go kart has battery technology with lifespan that is better for efficiency performance.

TABLE 2. Comparison on battery types

Battery Type	Energy Density (Wh/kg)	Power Density (W/kg)	Cell Voltage (V)	No. of Cycles	Operating Temp. (°C)
Lead-Acid [16]	25-35	75-130	2.1	200-400	-18 to 70
Valve Regulated Lead-Acid (VRLA) [17]	35-42	240-412	-	500-800	-
Nickel-Metal Hydride [18]	50-80	150-250	1.35	600-1500	-20 to 65
Nickel-Cadmium [19]	35-57	50-200	1.35	1,000-2,000	-40 to +60
Lithium-Ion [20]	100-150	300	3.6	400-1200	-20 to 60
Zinc-Bromide [21]	56-70	100	1.79	500	-
Lithium Polymer [22]	100-155	100-315	-	400-600	60-100
NaNiCl (Zebra batteries) [23]	90	100	2.08	N/A	270-350

Battery selection for electric Go Karts is critical and is based on calculated power requirements essential for achieving desired performance outcomes. The appropriate battery size can be determined based on the Go Kart's total weight, desired acceleration, and top speed. For a Go Kart weighing 200 kg with a goal of reaching 60 km/h in 5 seconds, the required power output can be estimated using the (1)

$$P = \frac{m * v^2}{2 * t} \quad (1)$$

where P is power, m is mass, v is velocity, and t is time. This calculation suggests a power need of approximately 5 kW battery to reach the desired performance. A lithium-ion battery, as shown in Figure 2, is rechargeable and efficient for this design. Moreover, this type of battery has a better lifespan compared to other types of battery.

FIGURE 2. Lithium Ion Battery

TABLE 3. Comparison of Brush and Brushless Motors

Characteristic	Brush Motor [24]	Brushless Motor
Simplicity	Applying brush motors is easier since commutation is done automatically by mechanical means. These motors can be driven directly by a DC power supply including a battery.	Applying brushless motors is relatively complex since commutation Is electronically controlled and directed by rotor position feedback from the motor, which requires drive electronics.
Torque	Generally higher for equivalent sizes.	Generally higher for equivalent sizes.
Speed	Recommended operating speeds between 1000 and 10,000 RPM.	Speeds in excess of 10,000 RPM are possible with appropriate designs
Noise	Highly audible and electrical noise due to brushes.	Quieter.
Life Expectancy	Life expectancies in the range of 2,000 to 5,000 hours of operation, typically limited by brush life.	Life expectancies more than 10,000 hours of operation, typically limited by bearing life.
Cost	Generally lower, especially when driven from a simple DC supply.	Generally higher.

Table 3 is a comparison between brush DC motor and brushless DC motors. Brushless DC motors seems better in terms of life expectancy and simplicity [25]. In electric DC motors, electrical current is passed through coils that are arranged within a fixed magnetic field. The current generates magnetic fields in the coils; this causes the coil assembly to rotate, as each coil is pushed away from the like pole and pulled toward the unlike pole of the fixed field.

Brushed DC motors consist of four key components; the stationary magnet (called a stator), the rotor, the commutator and the brushes. The rotor consists of one or more windings of wire wrapped around a core made of a ferrous metal, usually iron, and connected to power with a metal ‘brush’.

Figure 3 shows a brushed motor controller. One of the biggest advantages of brushed DC motors is that they offer simple speed control without the need for complicated electronics. Instead, the speed is controlled using variable supply voltage. The voltage is applied proportionally to the rotational speed, while torque is proportional to the current. It is suitable for electric scooters, e-bikes, tricycles, minibikes, pocket bikes, go karts, all-terrain vehicles and mopeds.

FIGURE 3. Brushed Motor Controller

C. Power Transmission System

The power transmission system in our electric go-kart is designed to optimize performance, efficiency, and reliability, comprising several key components. The chain drive, a common transmission system in go-karts, transfers power from the motor's sprocket to the rear axle sprocket, chosen for its simplicity, cost-effectiveness, and ease of maintenance. High-quality chains and sprockets are selected to ensure durability and efficient power transfer. The sizes of the motor sprocket and axle sprocket are carefully chosen to achieve the desired gear ratio, balancing the need for quick acceleration with a high-top speed. The rear axle, made of hardened steel, is supported by high-performance bearings to reduce friction and ensure smooth rotation. Additionally, the throttle control system, typically managed by an electronic speed controller (ESC), regulates the power delivered from the battery to the 36V brushless DC motor, allowing precise control over the go-kart's speed.

The selection of the 36V 500W lithium battery is critical to meet the power requirements of the go-kart. The motor's power rating is 500W, and it operates at 36V, drawing approximately 13.9A. This calculation ensures that the battery can supply the necessary current to drive the motor effectively. The battery must match the motor specifications, providing 36V and handling the current draw of around 13.9A. Its capacity, measured in ampere-hours (Ah), determines how long the go-kart can run before needing a recharge. For example, a battery with a capacity of 20Ah can theoretically provide 20A for one hour, translating to about 1.4 hours of operation at a continuous draw of 13.9A under optimal conditions. The battery's discharge rate, or C-rate, is sufficient to handle bursts of power during acceleration without degrading its lifespan. The 36V lithium battery is chosen for its high energy density, providing significant power without adding excessive weight, crucial for maintaining the go-kart’s performance and handling. Furthermore, lithium batteries are known for their reliability and safety features, including overcharge and short-circuit protection. Selecting a high-quality battery from a reputable manufacturer ensures consistent performance and longevity, reducing the risk of malfunctions or safety hazards. By thoroughly analyzing these factors, we ensure the battery meets the go-kart's power and performance requirements effectively and efficiently.

TABLE 4. Battery Comparison

Characteristic	Lithium-Ion Battery	Nickel Metal Hydride (NiMH) Battery
Energy Density	150-250 Wh/kg	60-120 Wh/kg
Weight	Lightweight	heavier than lithium-ion
Cycle Life	500-2000 cycles	300-500 cycles
Charging Time	1-4 hours for a full charge	2-6 hours for a full charge
Environmental Impact	Recyclable	Recyclable
Cost	$100-300	$200-400

TABLE 5. Motor Controller Comparison

Characteristic	**Brush Motor Controller**	**DC Motor Controller**
Efficiency	85-95%	70-85%
Lifespan	10,000+ hours of operation	2,000-5,000 hours of operation
Control Precision	High precision in controlling speed, torque, and position is essential for applications requiring fine-tuned performance.	Simpler control systems suffice for less demanding applications, does not need fine control capabilities
Complexity	manage precise control and feedback systems.	easier to implement and maintain, suitable for basic applications.
Cost	$100-$500	$50-$200

IV. RESULTS AND DISCUSSION

A. Battery Comparison

In Table 4, the comparison of both lithium-ion and nickel metal hydride batteries has been discussed.

Lithium-ion batteries offer high energy density, making them ideal for applications where weight and size are critical factors, such as in electric vehicles and portable electronic devices. Nickel metal hydride Battery provides moderate energy density, suitable for applications where a balance between performance and cost is required, such as in hybrid vehicles and power tools.

Lithium-ion batteries are lightweight due to their high energy density, making them preferred for portable devices and electric vehicles where weight reduction is essential. Nickel metal hydride battery is moderately lightweight compared to alkaline batteries but heavier than Li-ion batteries.

Lithium-ion battery offers a long cycle life, capable of enduring hundreds to thousands of charge-discharge cycles, depending on usage and maintenance. Nickel metal hydride battery provides a limited cycle life compared to Li-ion batteries, typically capable of enduring several hundred cycles before noticeable degradation.

Lithium-ion battery has fast charged capability, allowing for quick recharge times compared to NiMH batteries. Nickel metal hydride battery has moderate charging time required, slower than Li-ion batteries but faster than lead-acid batteries.

Lithium-ion battery has moderate environmental impact. It is recyclable but requires proper disposal methods due to the presence of toxic chemicals. Nickel metal hydride battery is similar to Li-ion batteries; they have a moderate environmental impact and are recyclable, but they also contain toxic materials.

Lithium-ion battery has higher initial cost due to advanced technology and higher energy density. Nickel metal hydride battery has moderate cost, making them a cost-effective option for applications where high energy density is not critical.

The power required to drive the go-kart was calculated based on factors such as vehicle weight, desired acceleration, and top speed. A lithium-ion battery was selected for its high energy density and long cycle life.

B. Motor Controller Comparison

In Table 5, the comparison of both brush motor controller and DC motor controller has been discussed.

Brush motor controllers offer high efficiency due to precise control of the motor's commutation, resulting in minimal energy loss and optimal performance. The DC motor controller provides moderate efficiency. While efficient, especially in well-designed systems, they may have slightly lower efficiency compared to brush motor controllers due to the absence of brushes and commutators.

Brush motor controllers offer a long lifespan, especially when paired with a well-maintained brushed DC motor. However, the brushes in brushed motors may be worn over time, affecting the overall lifespan of the system. The DC motor controller provides a moderate lifespan. While the controller itself may have a long lifespan, the overall system's longevity depends on factors.

Brush motor controllers offer precise control over the motor's speed, torque, and direction, making them suitable for applications requiring high control precision and accuracy. DC motor controller provides basic control precision. While DC motor controllers can regulate speed and direction, they may not offer the same level of precision as brush motor controllers, especially in demanding applications.

Brush motor controllers have a moderate level of complexity due to the need for precise commutation control and advanced electronics. They may require more sophisticated control algorithms and circuitry. DC motor controllers have lower complexity compared to brush motor controllers. DC motor controllers often utilize simpler control schemes and electronics, making them easier to implement and maintain.

Brush motor controllers come with a higher cost compared to DC motor controllers due to their advanced features, precise control capabilities, and potentially more complex design. DC motor controllers offer a lower cost compared to brush motor controllers. They are often more affordable and readily available, making them a preferred choice for budget-conscious applications.

C. Motor Comparison

In Table 6, the comparison of both brush DC motor and in-hub motor has been discussed.

In-hub motors are integrated directly into the wheel hub, which simplifies the overall design of the vehicle. Integration into the wheel hub allows for compact and streamlined vehicle designs. Brush DC motors are external to the wheel hub and require additional components such as gears, belts, or chains to transmit power from the motor to the wheels.

In-hub motors require low maintenance since they are enclosed within the wheel hub and are protected from external elements such as dirt, debris, and moisture. Maintenance typically involves periodic inspection and lubrication. Brush DC motors maintenance requirements are moderate as they are external components exposed to environmental factors. Brushes and commutators may require periodic replacement or servicing to maintain optimal performance.

In-hub motors offer high efficiency as power is directly transmitted from the motor to the wheel without the need for additional transmission components, reducing energy losses. Brush DC motor provides moderate efficiency. While efficient, brush DC motors may have slightly lower efficiency compared to in-hub motors due to additional transmission components and mechanical losses.

In-hub motor provides moderate control precision. In-hub motors offer good control over speed and torque, but they may not offer the same level of precision as brush DC motors in certain applications. Brush DC motor offers basic control precision. Brush DC motors can be precisely controlled for speed and direction, making them suitable for various applications requiring basic control.

In-hub motors have moderate complexity due to integration into the wheel hub and associated electronics. While complex compared to traditional brushed DC motors, in-hub motors offer simplified vehicle designs. Brush DC motors have lower complexity compared to in-hub motors. Brush DC motors are relatively simple in design and construction, consisting of a rotor, stator, brushes, and commutator.

In-hub motor comes with a moderate cost due to the integration into the wheel hub and associated electronics. While initially more expensive than brush DC motors, in-hub motors offer benefits such as compactness and efficiency.

TABLE 6. Motor Comparison

Characteristic	In-hub Motor	Brush DC Motor
Integration	Integrated into wheel hub	External
Maintenance	lower maintenance requirements	replace brushes and perform other maintenance tasks
Efficiency	85-95%	70-85%
Control Precision	requiring good control over speed and torque	requiring simple speed and direction control.
Complexity	provides a balance between advanced functionality and maintainability.	easy to manufacture, implement, and maintain
Cost	\$200-\$500	\$50-\$200

Brush DC motors offer lower cost compared to in-hub motors. Brush DC motors are simpler in design and construction, resulting in lower manufacturing costs.

V. CONCLUSION

In conclusion, the paper presented the importance of understanding user and market requirements during the design phase of an electric go-kart. Performance, safety, and cost-effectiveness are some of the major elements impacting go-kart design that were identified through extensive market research and consumer preference analysis. This information was used as a starting point to create innovative conceptual designs that satisfied the needs of the intended audience.

The adoption of state-of-the-art technology methods and concepts, such as CAD and comprehensive prototype testing, enhanced the reliability and efficiency of the go-kart. Research into aerodynamic resistance, new lightweight materials, and a more efficient powertrain contributed to improved performance without compromising safety features.

Iterative prototype testing provided valuable data on the go-kart's performance characteristics, robustness, and safety features. These results guided the optimization of the system, leading to improved performance, efficiency, and user experience.

Summarily this paper demonstrates the successful integration of engineering practices, user-centric design concepts, and advanced technologies to achieve the project’s objectives. The findings from this research offer valuable insights for future developments in electric go-kart design.

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