MECHANICAL MODIFICATION OF REMOTE-CONTROLLED (RC) GO-KART

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Abstract

This paper presents the design and develop mechanical modifications for a go-kart. The project encompasses the description of modifications to the throttle, brake, and steering systems, as well as the static control of the integrated system. To determine the required load, a measurement process is conducted. Subsequently, conceptual designs for the pedal system and steering system are generated and evaluated. The component selection follows a series of theoretical analyses. The chosen design undergoes static analysis using Finite Element Analysis in SolidWorks software. A simulation is performed to determine the stress exerted on the entire system. The location and magnitude of the maximum stress are identified to ascertain the safety factor of the system. The arrangement of the system is planned through packaging layout design. The fabricated parts of the pedal and steering systems are able to withstand the operational load based on the design specifications.

Keywords

Go-kart, Remote Control, First Person View, Finite Element Analysis

1.0 INTRODUCTION

Go-karting is a popular racing sport enjoyed by groups of friends and family at dedicated go-kart tracks. In parallel, the demand for Remote Control (RC) vehicles is also growing steadily. To meet these two demands simultaneously, an innovative approach is required by combining the two games. This innovation could serve as a catalyst for advancements in the racing sport.

An RC vehicle is a remotely operated vehicle that relies on essential components such as a motor, power supply, transmitter, and receiver. The RC vehicle incorporates a power unit comprising a riding motor and gear mechanism, a control unit for receiving and executing commands from the power supply, and a battery unit for power supply (Kattamis et al., 2001). From a mechanical standpoint, the RC vehicle can be implemented using the drive-by-wire concept, which involves replacing mechanical systems with electronic and electrical systems (Kan et al., 2006). Steering, braking, acceleration, and flight are examples of operations that can be accomplished with drive-by-wire technology. The conventional mechanical linkage between the steering rod and the road wheel actuator is replaced with a steering-by-wire system, incorporating electronic sensors, control systems, and actuators. The steer-by-wire system is gaining popularity due to its efficient and precise operations, as it operates automatically compared to the traditional mechanical system (Dahab, 2015).

Another innovation that follows the drive-by-wire concept is the design and operation of a brake and throttle robot (BTR), which was developed through extensive vehicle surveys (Coovert et al., 2009). Factors such as the position and angles of the gas and brake pedals, required force, and potential installation methods were considered during the creation of the BTR (Schwartz, 2017). The BTR prototype utilized a high-torque servomotor to power a precise ball screw, which drove the brake and accelerator pedals through mechanical linkages, depending on the direction of rotation.

The literature reviews on these subjects have inspired the idea of implementing mechanical modifications to transform the go-kart into a remotely controlled vehicle. This paper focuses on the design and development of mechanical modifications for the RC go-kart, incorporating a First-Person View (FPV) system. It involves designing the necessary actuators for the integrated system and creating compartments to house the electrical components. The scope of this paper encompasses the design and modification of the throttle, pedal, and steering systems, as well as the packaging layout, installation, and static control of the integrated system.

2.0 METHODOLOGY

In this project, there were three main components that needed to be designed: the actuator and motor placement for the throttle pedal, brake pedal, and steering. To complete all the designs, each component was divided to undergo into two processes: the preliminary design and the final design. In the preliminary design phase, the focus was on the design concept, which involved generating the initial idea and interpreting it visually. The final design provided a detailed document consisting of a list of features related to each component, known as design specifications, as well as design analyses (Chauhan et al., 2016).

2.1 MEASURING PROCESS

When producing an RC go-kart, it is crucial to consider the load on the go-kart. This is necessary to ensure that the torque provided by the motor is sufficient or higher than the mechanical torque required by the pedals or steering. For the throttle pedals, the tension arises from the throttle cable, which connects to the throttle body. On the other hand, factors such as road conditions, hydraulic pump pressure, and brake pad stiffness influence the force necessary to trigger the brake pedal. To measure the force required to engage the brake, a hook-type weighing scale was utilized. The force values obtained for the throttle and brake pedals are presented in Table 1.

Table 1: Resultant force at throttle and brake pedal

Pedal	Minimum force (N)	Maximum force (N)	Average force (N)
Throttle	34.323	44.123	41.678
Brake	61.782	83.356	72.569

On the steering system, the load was measured using a torque wrench. An adjustable three-claw spiral oil filter wrench was attached to the head of the torque wrench and secured at the center of the steering. The torque wrench was positioned at a 0-degree angle and turned in an anticlockwise direction until the steering began to move. Figure 1 illustrates the types of forces present in the steering system before it can be steered. The measured torques on different types of road contact are presented in Table 2. The readings taken represent the maximum torque derived from the maximum static frictional force exerted by the tire, preventing the go-kart from sliding.

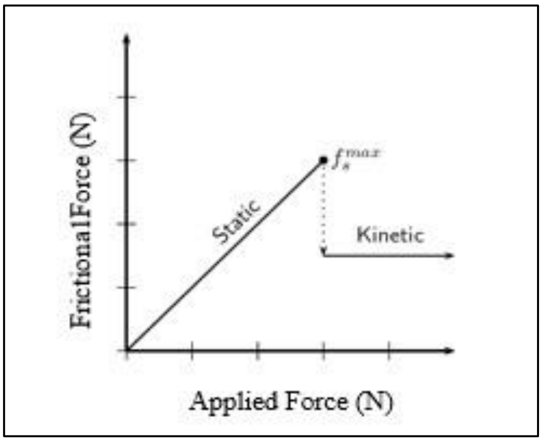


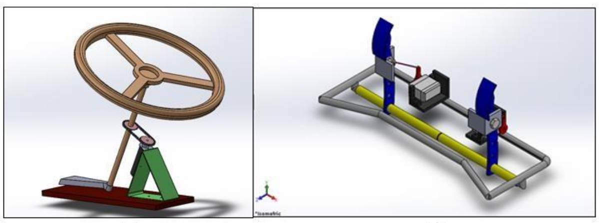
Figure 1: Graph of frictional force against applied force

Table 2: Maximum torque of steering at different road condition

Contact Road	Maximum torque (Nm)
Dry road	21.0
Cement	18.0
Wet road	19.5

2.3 DESIGN SELECTION

In the pedal system, two servo motors were employed to operate the accelerator and brake pedals. The motor and the pedals were connected using a high-tension brake cable bike. As for the steering system, torque was transferred from the DC motor to the steering mechanism through sprockets and a chain. A High-Power Planetary DC Geared Motor with a torque of 25Nm was utilized. This torque value proved to be adequate for rotating the steering on any type of road contact. The sprocket ratio implemented was 1:1. The motor and steering were connected using a chain and sprocket mechanism. Subsequently, the design was modeled using Computer-Aided Drawing (CAD) software (Figure 2).



(a) (b)

Figure 2: Modelling view of design selection

2.4 MOTOR SELECTION

When selecting a motor for the system, it is important to consider the type that can deliver an adequate amount of torque. The servo motor emerges as the optimal choice since it offers nearly precise rotation for both the accelerator and brake pedals. This ensures efficient control over the accelerator and brake functions. The required torque at the pedals can be calculated by considering the resultant moment at the servo arm.

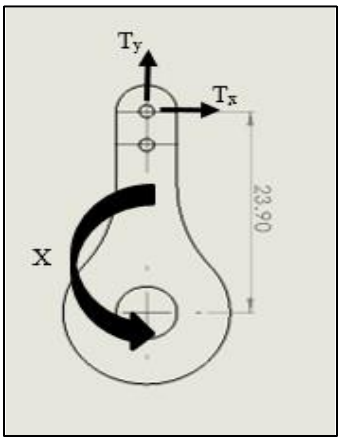


Figure 3: The resultant moment at servo arm

$$\sum M = X - T_x l = 0 \quad (1)$$

By referring to Figure 3 and equation (1), the required moment denoted as M can be determined. In the equation, l represents the length between the center of the servo arm teeth and the cable slot, while Tx represents the maximum force needed to engage the pedal. According to Table 1, the force required to pull the throttle pedal, Txa, is measured at 44.130 N, whereas for the brake, the required force Txb is 83.357 N. As Ty is aligned with the pivot, there is no moment exerted in that direction. The X component refers to the amount of moment needed to engage the pedals. The torque required at the throttle pedal is calculated to be 1.058 Nm, while the brake pedal necessitates 1.992 Nm. Therefore, the selected servo motor MG996r Tower Pro proves to be sufficient in pulling the accelerator pedal with a torque of 1.0787 Nm, while the brake pedal requires a DS3218 RC Servo Torque Servo Motor with a torque of 1.9 Nm at a 5V power supply and 2.1 Nm at 6.8V.

2.5 CABLE SELECTION

In the throttle and brake pedal system, the cable serves as the medium that connects the servo motor to the pedal. It is crucial to use a cable that can withstand the force generated by the motor to engage the pedal effectively. If the cable fails to withstand the stall load, there is a risk of it snapping. The tension experienced by the cable can be calculated using coordinate method analysis.

$$T = T_x \frac{d_x}{d} i + T_y \frac{d_y}{d} j + T_z \frac{d_z}{d} k \quad (2)$$

The tension of the cable is represented by T, while Tx denotes the maximum tension required to engage the pedal along the x-axis. Similarly, Ty and Tz represent the maximum tension needed to engage the pedal along the y and z-axis, respectively. The values of dx, dy, and dz indicate the distances between the pedal and servo arm along the x-axis (53.84 mm), y-axis (30.25 mm), and z-axis (22.84 mm) respectively. The value of d is given by

$$d = \sqrt{{d_x}^2 + {d_y}^2 + {d_z}^2}$$
$$= \sqrt{53.84^2 + 30.25^2 + 22.84^2}$$
$$= 65.84\ mm \quad (3)$$

The cable tension at the throttle pedal measures 36.085 N, whereas for the brake pedal, the tension amounts to 68.160 N.

2.6 ROLLER CHAIN AND SPROCKET SELECTION

The roller chain and sprocket drive are the systems that will be implied in the steering system. This method allows the torque generated by the DC motor to be transmitted to the steering. Usually, the roller chain is made of steel while the sprocket is made of from the high grade cast iron (M. Houben, 2004). The driven gear is connected to the steering rod while the driven gear is connected to the DC motor.

3.0 RESULTS AND DISCUSSION

3.1 FINITE ELEMENT ANALYSIS

To ensure the structural integrity of the integrated system and prevent failure due to stress, it is essential to analyze its structure using Finite Element Analysis (FEA) simulation. This analysis aims to determine the static control of the integrated system. For this purpose, solid modeling computer-aided design (CAD) software SolidWorks was utilized. Figure 4 presents the simulation result of the stress analysis conducted on the throttle and brake pedal.

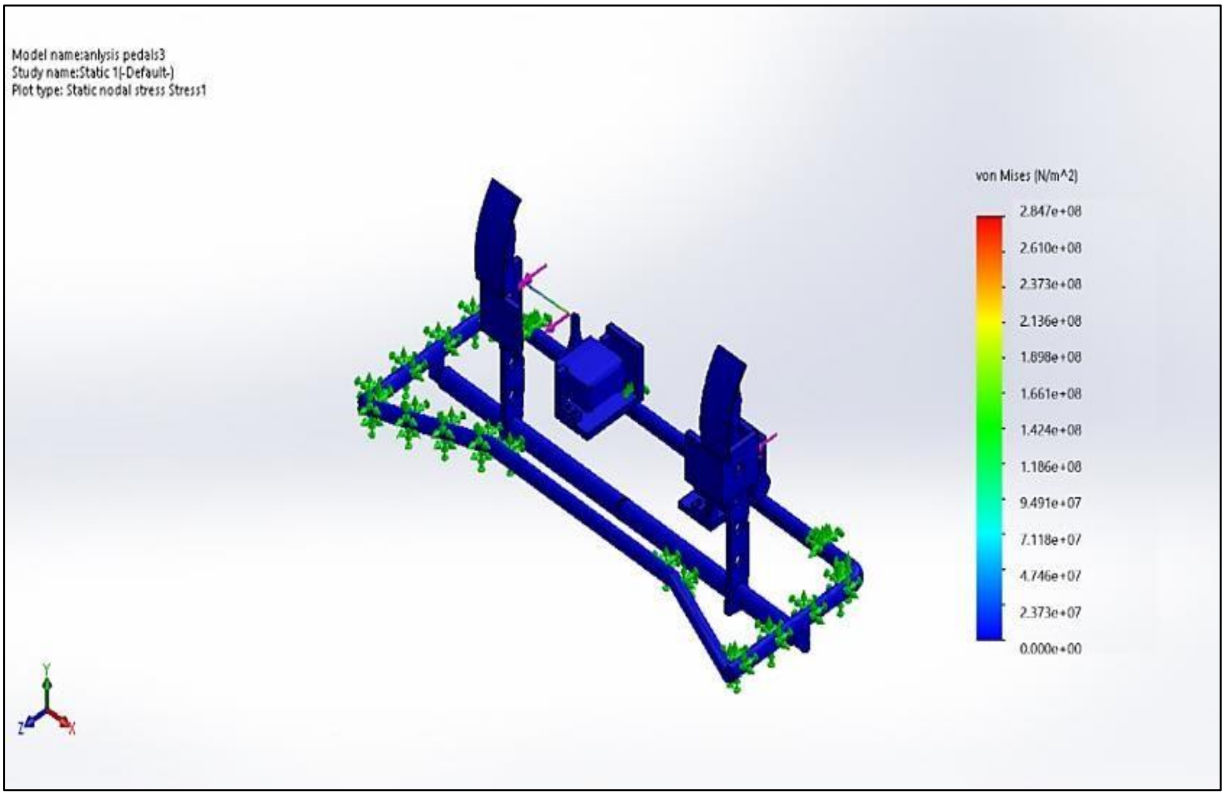


Figure 4: Simulation result at pedals system

The simulation employs the von Mises stress criterion to predict yielding in each material. According to the results, the cable responsible for engaging the brake pedal experiences the maximum stress due to the required load of 83.356 N. The magnitude of the maximum stress is measured at 0.2847 MPa. The cable is composed of stainless steel material with a yield strength of 0.741 MPa. Consequently, the safety factor can be calculated using the safety factor equation.

$$SF = \frac{\delta_{yield}}{\delta_{max}} \tag{4}$$

The safety factor (SF) is calculated using the equation that involves the material yield stress ($\delta yield$) and the maximum stress experienced by the system (δmax). In the case of the pedal system, the calculated safety factor is 2.604. Since the value of the safety factor is greater than one, the design can be deemed safe.

Figure 5 illustrates the simulation result of the stress analysis conducted on the steering system. Similar to the previous analysis, the von Mises stress criterion is utilized to identify potential yielding in the system's components. Upon examining the generated result, it is observed that the maximum stress occurs at the coupling, which connects the drive sprocket with the Planetary Geared High Torque DC Motor, with a magnitude of 0.127 MPa. The torque generated by the DC motor amounts to 25 Nm. The coupling material is composed of ASTM A36 steel, which possesses a yield strength of 0.25 MPa. Employing equation (5), the safety factor of the material is determined to be 2.434..

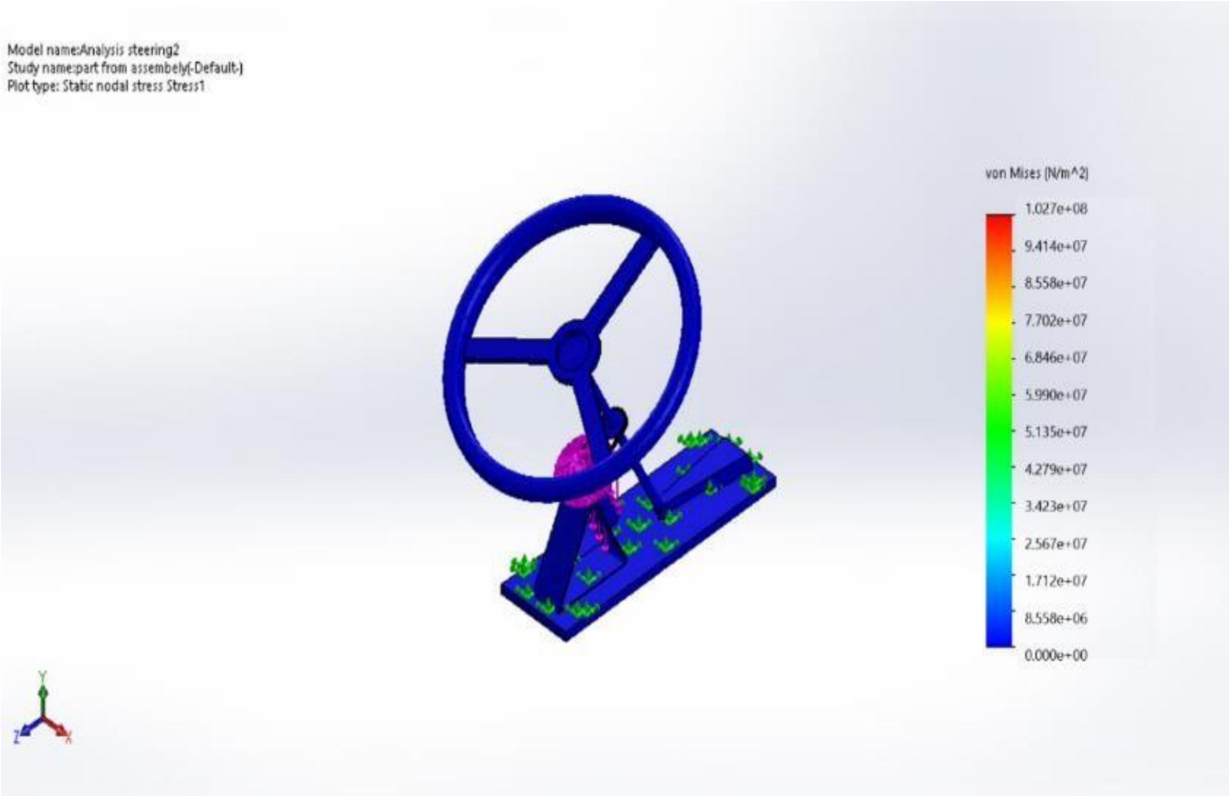


Figure 5: Simulation result at steering system

3.2 PACKAGING LAYOUT

The assembly of the fabricated parts must be carried out meticulously according to the established plan. This step is of utmost importance to mitigate the risks of issues, failures, and disorderliness within the mechanism. Figure 6 provides a visual representation of the packaging layout for the go-kart. The pedal system is positioned at the front of the go-kart, with the pedals situated behind it. The steering system is attached between the driver seat and the steering rod. Additionally, the Arduino unit is placed between the pedal system and the steering system to facilitate the distribution of cable harnesses to the respective systems. The RC transmitter is located adjacent to the Arduino placement. Furthermore, the FPV system is implemented above the driver's seat to provide a driver's perspective while operating the go-kart. This arrangement also grants users the opportunity to operate the go-kart manually, if desired.

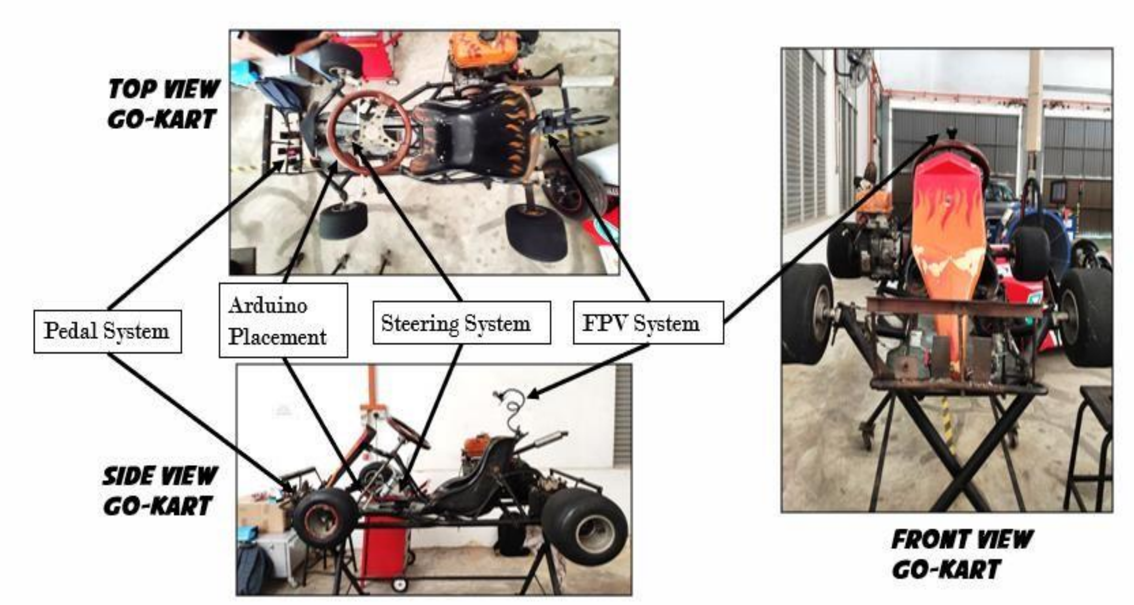


Figure 6: The packaging layout of the go-kart

Figure 7 provides an illustration of the throttle and brake pedal view. The components present in the pedal system include servo motors, servo motor holders, servo arms, cables, and cable clamps. It's worth noting that the servo motor used to engage the throttle pedal differs from the one used for the brake pedal. This distinction arises from the varying load requirements to engage each system. The servo motor holder is securely welded to the front frame of the go-kart to ensure a rigid and stable placement.

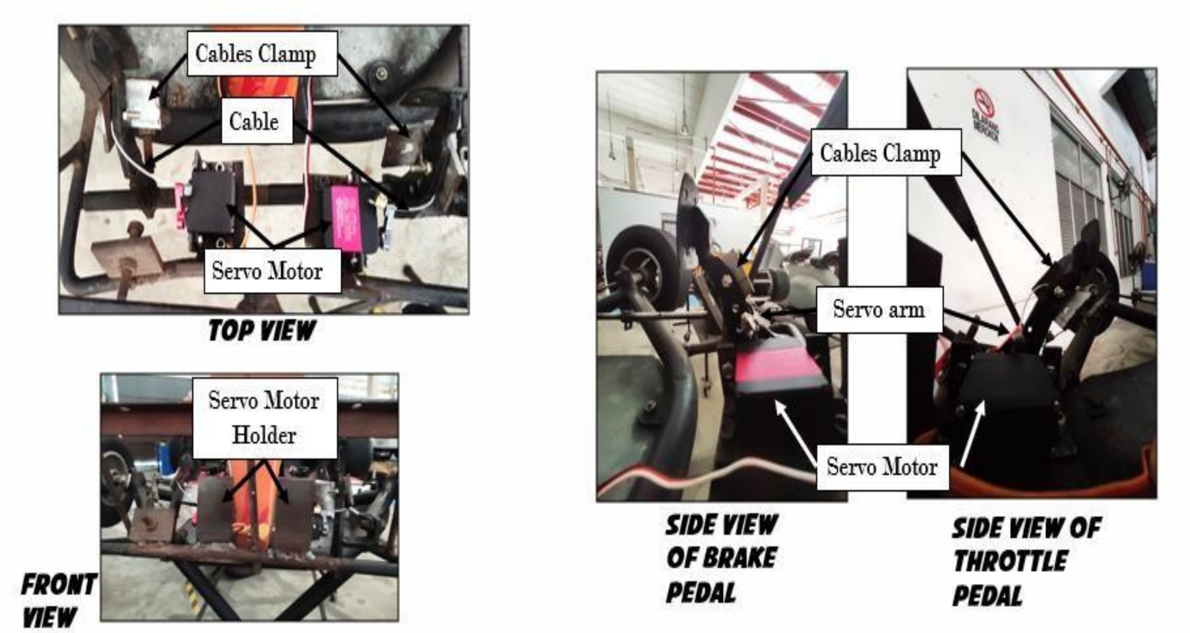


Figure 7: The packaging layout of the pedal system

Figure 8 depicts the packaging layout of the steering system. The driven timing sprocket is welded to the steering rod, ensuring a secure connection. The DC motor holder is attached to the base using bolts and nuts. To facilitate the operation of the sprockets and chain, it is crucial that both sprockets are parallel to each other. For this reason, the DC motor is positioned at an angle of 60 degrees from the ground, ensuring it is parallel to the steering rod and perpendicular to the sprockets. The DC motor adapter is welded to the drive sprockets and securely fastened to the output shaft of the DC motor using screws.

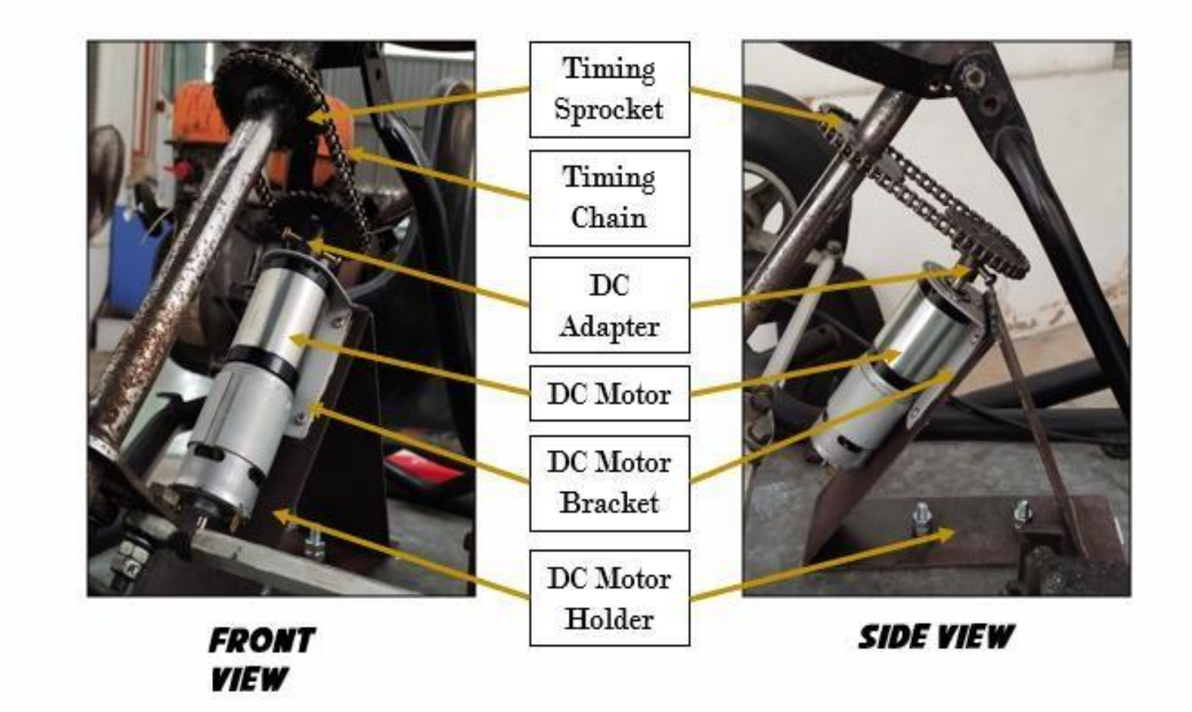


Figure 8: The packaging layout of the steering system

4.0 CONCLUSION

The objective of this project is to design and implement mechanical modifications to the RC go-kart's First Person View (FPV) system. The main focus is on modifying the existing accelerator, brake, and steering systems to transform the traditional go-kart into an RC system. The design process involves determining the appropriate actuators and their placement through conceptual design. Experimental data is collected to determine the maximum tension and torque required by each system. Through calculations, it is verified that the selected motors are capable of handling the maximum tension and torque requirements. The integrated system undergoes static control analysis using SolidWorks' Finite Element Analysis (FEA) tool. Based on the analysis results, it is concluded that the design of the integrated system is safe for fabrication. A packaging layout is developed to ensure that the components fit securely within the go-kart.

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