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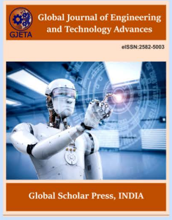


(Research Article)

# Modeling and simulation analysis of racing Go-kart-The brake system

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## Abstract

Go-karts are a type of minicar that are used for racing and other types of leisure racing. There are extremely popular in countries that have an industrialized economy, and their popularity is quickly growing in countries that are still developing their economies. The performance of the vehicle is determined by a number of factors, the most important of which are the engine, the transmission, the chassis, and the braking system which serves as the lifeline of the vehicle. Even though there is no suspension or differentials, the chassis is nevertheless very flexible, so it can handle corners and dips just well. This Go-kart is driven by a Yamaha Vino Automatic Petrol 2-Stroke Engine, which is capable of producing around 4.1 kilowatts of power at 9018 revolutions per minute. Slick tires and a hydraulic disc brake make it easy to come to a stop in any condition, whether it's dry or wet outside. The braking system and the material qualities of its structural components receive the majority of attention throughout this research. The following information was uncovered by a static simulation analysis performed using SolidWorks: The density of the material is 7700 kg/m$^3$, the yield strength is 6.20422e+08 N/m$^2$, and the maximum tensile strength is 7.23826e+08 N/m$^2$. During the course of the design phase, the best possible solution was identified. Ergonomics, safety, cost of manufacturing, and reliability are all considered.

**Keywords:** Go-kart; Vibrations/stress analysis; Ergonomics; Simulation; Braking System

## 1. Introduction

In developed nations such as the United States, go-karts—four-wheeled, single-seat racing vehicles with a small engines—are extremely popular. These were created in the 1950s by bored airmen during the postwar period. Go-karts often do not utilise differentials due to their diminutive size [1-4]. Karting is a well-liked leisure activity among Formula 9 sports [5-8]. Go-karts powered by gasoline, electricity, solar energy, and hybrid engines are available on the market.Despite the fact that they are typically only raced by professionals on smaller tracks, regular people can still use them as a recreational activity. Typically, a driver's career in motorsports begins in karting.

Engineers in the modern era are diligently developing and refining safer automobiles by enhancing their design and materials. Load testing is one of a battery of tests used to measure the effectiveness of a vehicle. In these tests, frontal, lateral, and oblique loads are simulated. The likelihood of experiencing vibrations and other stressors is diminished. Today, testing and analysis of Go-karts are more important than theoretical conclusions because this type of vehicle is used for racing and requires a high level of safety. Due to their greater financial and physical accessibility, these vehicles have surpassed their more expensive and larger counterparts in the racing and sports car markets. It is gaining popularity among all age groups, including children, adults, and the elderly. The industry is thriving, and the future looks promising

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The braking system of a racing car serves multiple functions, including slowing the vehicle around corners and bringing it to a complete stop. As the most active component of a vehicle, this system is subject to the most wear and tear as a result of the intense heat generated by friction near the tires. However, in a Go-kart racing vehicle, stopping power is more crucial than durability. In addition, cost is not a major concern because a limited number of vehicles are being manufactured for a highly publicized event. Go-karts have a lower body weight than passenger vehicles and other racing cars; 75% of the total body weight comes from the engine, which is roughly as heavy as a two-engine wheeler's [9]. According to Mitchell et al.'s[10] analysis of the design of go-karts, the distance between the front and rear wheels serves as the vehicle's foundation. In other words, the larger the base of the vehicle, the more stable and dependable it will be. Different types of go-kart designs required distinct measures of vehicle stability, according to the research. Since Go-kart designs must be updated over time, the study also recommended that advancement should not be halted [10].Hajare et al. [11] conducted research on the aerodynamic qualities of the automobile. Based on aerodynamic principles, they investigated the optimal packaging of the engine and the most efficient design for the vehicle's body. The following two modifications will result in a significant increase in top speed. The selection of a vehicle's braking system should correspond to its speed.

Local kart enthusiasts and operators, especially in developing countries, are left with no choice but to import them from abroad due to the need to demonstrate practical skills and theoretical knowledge in the design of machine elements that contribute to the automobile industries. In turn, this causes the price to rise significantly, which may put off some sports fans. While the benefits of utilizing a Go-kart for racing are obvious, the point has to be made. In countries where go-karts have not yet become popular enough to draw considerable investment in their design and development, only approximately 15 percent of the population uses or visits amusement parks or recreational facilities [12]. It's useful for people of all educational and occupational backgrounds. The several local factories that make go-karts for fun and racing provide employment for some of the area's engineers. It's safe to assume that many enterprising people would jump at the possibility to enrich themselves, their families, and their countries (particularly via soccer matches and other athletic events), so boosting the GDP and extending the economic base [13].

This research aimed to produce a one-of-a-kind Go-kart based on a revised concept design, with modifications made to improve the vehicle's stability and evaluate the effectiveness of its braking system, the construction and design of a car should prioritize user-friendliness and efficiency, the primary design objectives were usability, reliability, and safety. in an effort to improve vehicle performance and durability while simultaneously reducing manufacturing complexity and costs, experts examined both essential components.

## 2. Material and methods

### 2.1. Material Selection and Characterization

Fabrication was done using mild steel because of its cheap cost, high strength-to-weight ratio, broad availability, and low manufacturing cost all of which combined to make it the material of choice. The qualities of mild steel are outlined below.

**Table 1** Mild steel properties

| Property | Values |
|---|---|
| Ultimate tensile strength | 835Mpa |
| Yield tensile strength | 232Mpa |
| Density | 7.87g/cc |
| Elongation of break | 18% |
| Bulk Modulus | 136Gpa |
| Poisons Ratio | 0.378 |
| Shear modulus | 79Gpa |

### 2.2. Sign Considerations

To build a high-performance racing vehicle that is safe, cost-effective, and ergonomic in every manner, designers take into consideration a variety of criteria, such as driver ergonomics, serviceability, maneuverability, the design of a flexible roll cage, and the use of maximum power efficiency [14].

### 2.3. Chassis Construction

The chassis construction supports the driver, engine, and bump loads (which in karts serve as suspension). The length of the kart was decreased by moving the brake and gas pedals to the front. Also, ensure that you are always at least 3 inches off the ground.

### 2.4. Steering Mechanism

The primary purpose of the steering system is to provide direction control with a small turning circle. The design process placed a focus on a low profile, a compact size, and a basic aesthetic. The vehicle's efficiency is heavily influenced by the speed and steadiness of the steering mechanism [15].

### 2.5. Selection of Engines

Typically, a go-engine kart's is fairly tiny. At 9018rpm, this kart's Yamaha vino automatic gasoline engine delivers about 4.1kw of power. Two-stroke engines are a typical kind of engine used in racing. Its powertrain provides all of the Kart's power characteristics, including top speed, acceleration, and torque. A chain transmission transmits the power from the motor to the drive shaft.

### 2.6. Production Methods

The technique of constructing this go-kart involves the following steps: Fabrication using standard metalworking processes such as Cutting, Drilling, Filing and welding.

### 2.7. Transmission system

When a chain is connected to a series of sprockets, the ensuing motion creates the required torque to propel the vehicle. While the driven sprocket has 45 teeth, the driving sprocket has just 15. As the Go-gearbox kart's transmission is automatic, the driver is not required to utilize a clutch or manual gear. The chain drive system is used to convey mechanical power to the two rear wheels due to its resistance to pressure, stronger impact for transmission over shorter distances, and wide application.

### 2.8. Tyres

Go-karts have substantially smaller tires and wheels than conventional automobiles. These tires provide greater durability and traction. Additionally, it is resistant to severe heat. This kart's front tires are 11 inches wide and its rear tires are 13 inches wide. This is how aerodynamic shapes are constructed. Each tire should have a minimum pressure of 18 pounds.

### 2.9. Go-Kart Design

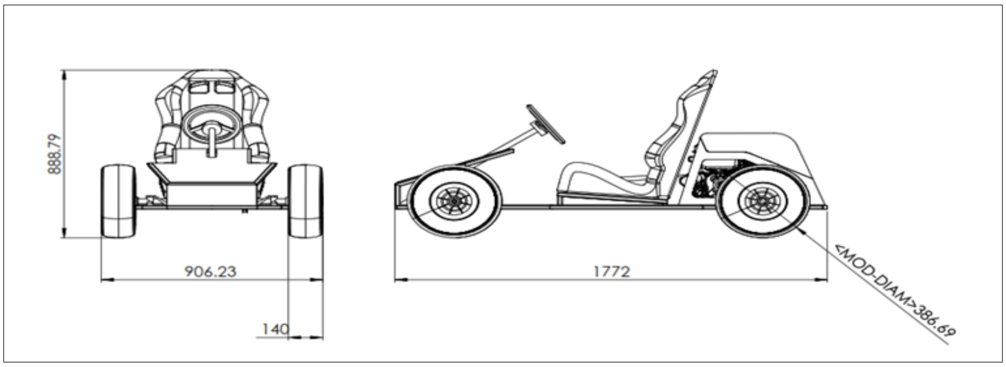


**Figure 1** 3D Design of the Go-kart

The estimated braking forces are established using the go-specifications kart's and current braking standards. Apart from that, the location of the brake caliper is known. Since it is unknown where the brake caliper assembly will be mounted on the vehicle chassis, the mounting position is not taken into account while doing a static analysis on the brake caliper assembly alone.

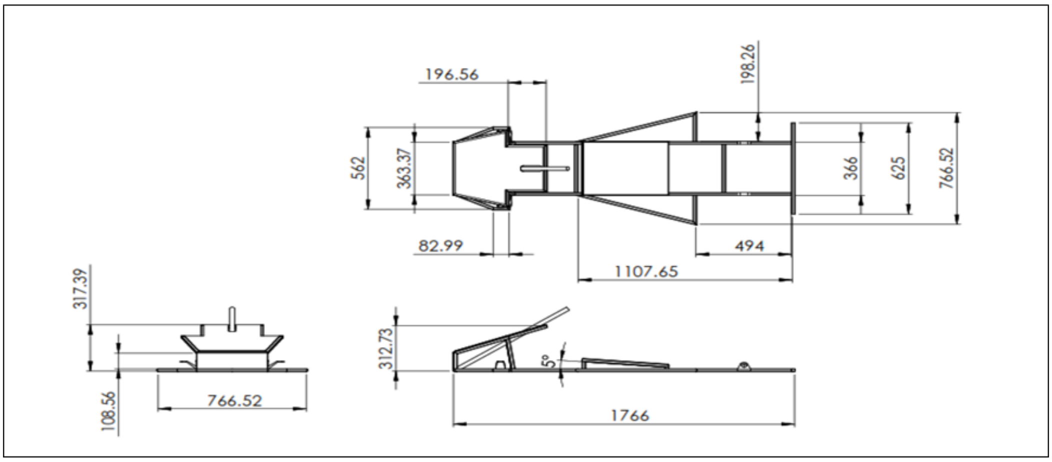


**Figure 2** 2D Design of the Go-kart structure

## 3. Results and discussion

### 3.1. Analysis of the Brake System

A vehicle's kinetic energy is determined by its mass and velocity while it is in motion and then comes to a halt or slows down. Braking causes the net kinetic energy of the vehicle to be transformed into heat due to the resistance provided by the caliper plate on the brake disc. To calculate the vehicle's kinetic energy,

$$\text{Kinetic energy, } = \tfrac{1}{2} m v^2 \quad \text{.......(1)}$$

Assuming the vehicle has a mass of 180kg, a speed of 16.67ms-1, and a kinetic energy of 25.01KJ. Rotational energy is given by

$$E = {}^{1}/_{2} I(W_1)^2 \quad \text{....... (2)}$$

Where; I is the mass moment of inertia and w is the rotational speed.As the speed of the vehicle decreases, it is believed that the coefficient of friction,, between the tire and the road does not increase to more than 0.6. We thus estimated that the vehicle's stopping distance was 5.88ms$^{-2}$

The vehicle's stopping distance may be determined using Newton's law of motion. That is for,

$$v^2 = u^2 + 2as \quad \text{....... (3)}$$

Where v and u for the vehicle's initial and final velocities and a and s for its initial and final accelerations, respectively. similarly, if we assume that v=0 after applying the brake, then u=16.67 m/s and a reduction in speed of 5.88 ms-2 is achieved by the vehicle, therefore the estimated distance(s) required to come to a complete halt will be 23.63 m.

Also, Time(t) to stop the car from Newton's law may also be obtained from;

$$v = u + at \quad \text{....... (4)}$$

If we assume that v = 0, u = 16.67 ms-1, and d = 23.63 m, then we get a stopping time of t = 2.84 seconds. Therefore, 2.84s is the time required to come to a halt inside 23.63m.

### 3.2. To simulate the impact of braking

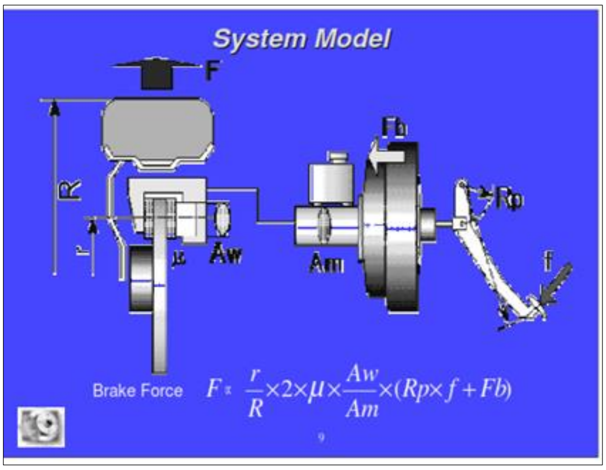


**Figure 3** Path of force from the driver's foot to the road surface

f = force applied by the driver's foot
$R_p$= lever ratio for the pedal
$F_b$ = booster assist force
$A_m$ = area of the master cylinder
$A_w$ = front caliper piston area
μ = lining friction coefficient
r = effective radius of the caliper
R = loaded radius of the tire.

The pressure (psi) in a hydraulic braking system is determined by the force applied to the brake pedal, the output of the booster, and the diameter of the master cylinder pistons, according to the same principles outlined by Ravindra L.G et al [16]. As the needed brake pedal power rises, the bore diameter of the master cylinder decreases. In order to displace the same amount of fluid, the piston in a smaller master cylinder would have to travel longer. As force applied to the brake shoes increases, the diameter of the wheel hub or caliper piston increases. Occasionally, it might be difficult to locate dependable information on the caliper effective radius and/or the tyre loaded radius.

Work performed = force distance may be used to calculate the braking force.

$$\text{Force} = {}^{25010}/_{23.63} = 1058.4N$$

Brake Torque = Brake Force × Effective radius of the rotor

$$\text{Effective radius} = {}^{(D + d)}/_{4} = {}^{(16 + 2.54)}/_{4} = 4.635cm$$

$$\text{Hence, Brake torque} = 1058.4 \times 0.04635 = 49.06Nm$$

By approximation, the amount of force the drive applies on the pedal is taken as 100 $N$ and the ratio of the pedal is 4:1.

The master cylinder piston area is $1cm^2$.

$$\text{Brake Pressure} = \text{pedal ratio} \times \text{pedal force} = 4 \times 100 = 4000KN/m^2$$

And;

Area of cylinder piston = $0.0001m^2$

**Table 2** Calculated data for the braking system

| Data Criteria | Values |
|---|---|
| Disk outer diameter | 16cm |
| Disk inner diameter | 2.54cm |
| Thickness of disk | 0.3cm |
| Brake pedal force | 100N |
| Pedal ratio | 4: 1 |
| Coefficient of friction | 0.60 |
| Brake line pressure | 4000KN/m2 |
| Brake torque | 49.06Nm |
| Stopping distance | 23.63m |
| Stopping time | 2.84s |

The preceding settings ensure that the brakes function as expected and per the requirements. Because they have a low specific gravity and need less energy to move, brake discs comprised of an aluminum metal matrix composite which were selected. The amount of energy a brake absorbs is proportional to the type of motion being halted (speed). A body's motion may be described by translation, rotation, or a combination of the two [17].

**Table 3** Study properties for simulation result analysis

| Study name | Static 1 |
|---|---|
| Analysis type | Static |
| Mesh type | Beam Mesh |
| Solver type | Direct sparse solver |
| Inplane Effect: | Off |
| Soft Spring: | Off |
| Inertial Relief: | Off |
| Incompatible bonding options | Automatic |
| Large displacement | Off |
| Compute free body forces | On |
| Chassis Material | Alloy Steel ERW (Linear Elastic Isotropic) |
| Mass Density | 7700 kg/m^3 |
| Yield Strength | 6.20422e+08 N/m^2 |
| Ultimate Tensile Strength | 7.23826e+08 N/m^2 |
| Elastic modulus/ Poisson's ratio | 2.1e+11 N/m^2/0.28 |
| Shear modulus | 7.9e+10 N/m^2 |
| Thermal expansion coefficient | 1.3e-05 /Kelvin |
| Default failure criterion | Max von Mises Stress |

**Figure 4** 3D Solid works model of the Go-Kart

## 4. Conclusion

Due to their rising popularity, manufacturing go-karts has become more labor-intensive. There are a few things to keep in mind when it comes to automotive engineering in general. Engineers may use this method in their pursuit of delivering the best possible ergonomic design Go-Kart. The chosen design is the safest and most dependable solution for any racing car due to its qualities and adaptability. Simulated static analysis results revealed a mass density of 7700 kg/m3, a yield strength of 6.20422e+08 N/m2, and an ultimate tensile strength of 7.23826e+08 N/m2. The design specifications account for usability, security, ease of manufacture, and dependability. Durability, standardization, cost, performance, aesthetics, ergonomics, pricing, and materials were all factors considered in this design. To avoid design failure, the loaded components were evaluated using solid-works analysis wherever possible.

## Compliance with ethical standards

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### *Disclosure of conflict of interest*

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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