Design and Fabrication of Car: A Comprehensive Approach by Undergraduate Engineers

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Abstract:

This paper explains the step-by-step process followed to design and fabricate a low-cost, lightweight car using easily available materials and components. The main goal was to gain practical knowledge by applying engineering principles such as mechanics, thermodynamics, materials science, and manufacturing techniques. The design process began with sketching and CAD modeling, followed by the fabrication of a tubular frame chassis using mild steel. A 150cc Bajaj Pulsar engine was selected for its compact size and reliable performance, and a chain drive was used to transmit power to the rear wheels. The car's body was made using umbrella cloth, chosen for its lightweight and flexible nature, which also helped reduce overall cost. Suspension, steering, and braking systems were custom-built and fitted as per design requirements. The entire assembly was carried out using basic tools in a college workshop setup. After fabrication, the vehicle was tested and found to perform efficiently under normal driving conditions. This paper discusses each stage of the project, along with the challenges faced during design and manufacturing, and the practical solutions adopted.

Keywords: Design, Fabrication, Chassis, Engine, Suspension, Prototype, Umbrella Cloth

1. Introduction:

The automobile is one of the most important inventions in modern transportation, widely used for travel, work, and goods movement. Designing and building a car helps in understanding how various mechanical systems like engine, transmission, suspension, and braking work together. This type of project gives engineering students a great opportunity to apply classroom knowledge in real-world applications. It also builds skills in teamwork, planning, and problem-solving. In this project, we focused on designing and fabricating a small, low-cost, single-seater car using locally available materials and simple tools. The car was designed with key factors in mind such as safety, comfort, strength, fuel efficiency, and cost-effectiveness. The structure was made from iron pipes, while the body was covered using umbrella cloth to keep the weight and cost low. A 150cc Bajaj Pulsar engine was used due to its compact size and reliable performance, making it ideal for this lightweight vehicle. This type of car is often called a Go-Kart a four wheeled, open-frame racing car that can be built and driven by both professionals and hobbyists. Go-Karts resemble Formula 1 cars in terms of their design concept but are far more affordable and easier to construct. They are especially popular in countries like the USA for recreational racing, and their popularity is rapidly growing in India due to the excitement they offer at a much lower cost. Go-Karts are lightweight, easy to operate, and typically use simple mechanical principles for construction. As more students and racing enthusiasts become involved, Go-Kart competitions are gaining attention. Designing such a vehicle involves both technical knowledge and creativity. Each team must carefully analyze various design challenges, test ideas, and find practical solutions to build a functional and competitive vehicle. This project was an opportunity to explore those challenges and achieve a working model through hands-on learning.

2. Literature Review:

Go-Karting is a growing field of interest in the automotive world, especially among students and amateur racers. It combines the principles of basic vehicle dynamics with hands-on fabrication techniques, making it an ideal learning platform. A review of previous literature highlights the historical evolution, technical definitions, and key components of Go-Kart design. As described by **Abdullah et al. [1]**, a Go-Kart is a land vehicle with four non-aligned wheels in contact with the ground. Two of the wheels are used for steering, while the other two are responsible for transmitting power. It may or may not have bodywork. The chassis typically consists of a framework made from bent steel tubes that are welded together. Essential parts include the frame, engine, wheels, tyres, and steering system. This basic yet functional design forms the foundation of most Go-Karts built today. The history of Go-Karts dates back to early developments in America. According to **Rong [2]**, quoting **Smith (3)**, the first Go-Kart was invented in 1956 by Art Ingels, a race car builder at Kurtis Kraft in California. Although initial versions were simple push-carts for children, Go-Karts eventually became a form of leisure motorsport after World War II. Despite their American origin, Go-Karts quickly gained popularity across Europe and other parts of the world. **Chauhan (2016)** pointed out that Go-Karts are lightweight, compact vehicles primarily used for racing purposes. Due to their low ground clearance, traditional suspension systems are usually not installed. This lightweight design helps maximize acceleration, as reducing vehicle mass increases the power-to-weight ratio. Go-Karts typically have high torque but lower top speeds compared to full-sized racing cars. Their simplicity, affordability, and ease of use make them a perfect starting point for beginner racers and automotive enthusiasts. Additionally, various Go-Kart competitions and design challenges such as SAEINDIA GKDC have encouraged student teams to apply engineering skills in a competitive environment. Literature from these events emphasizes practical concerns like safety, ergonomics, braking efficiency, and frame durability. Learning from past design projects helps new teams avoid common mistakes and improve performance. In summary, the literature reveals that Go-Kart design has evolved from basic carts to performance-focused vehicles. Understanding historical background, design principles, and technical challenges is essential for developing a safe, efficient, and innovative Go-Kart.

3. Objectives

The primary goal of this project is to design and fabricate a safe, functional, and cost-effective Go-Kart while gaining practical knowledge in vehicle dynamics and subsystem integration. The following specific objectives were identified:

3.1 Design and Fabrication Objectives

1. **Design a lightweight and durable chassis** using suitable materials that provide structural strength without adding unnecessary weight.
2. **Build a cost-effective and reliable vehicle** using locally available components and simple manufacturing methods.
3. **Integrate key automotive subsystems** such as the engine, braking system, steering, and transmission to ensure proper coordination and performance.
4. **Test and evaluate the Go-Kart** under real-world conditions to assess its handling, acceleration, braking, and overall reliability.

3.2 Performance and Driver Skill Objectives

5. **Improve lap times progressively** by practicing smooth driving techniques and optimizing each turn on the track.
6. **Develop race craft skills** such as effective overtaking, defensive driving, and navigating through traffic in a competitive racing environment.
7. **Enhance core driving techniques**, including proper braking, throttle control, and cornering, to improve overall driving efficiency.
8. **Understand and memorize the track layout**, focusing on ideal racing lines to increase speed and reduce time per lap.
9. **Maintain consistency in performance** by aiming for uniform lap times throughout practice or competition sessions.
10. **Optimize Go-Kart setup**, experimenting with adjustments in tire pressure, wheel alignment, and chassis tuning to suit the driver’s style and track conditions.

11. **Apply race strategies** such as fuel management, timing of pit stops, and tactical driving to gain a competitive advantage.
12. **Ensure safety at all times** by following track regulations, wearing proper protective gear, and regularly checking vehicle components.

4. Main Components of a Go-Kart

A Go-Kart is a compact racing vehicle made of several key components that work together to deliver speed, control, and stability on the track. Each element must be carefully selected and designed for optimal performance, safety, and durability.

4.1 Chassis (Frame)

The chassis, often referred to as the backbone of the Go-Kart, is the structural frame that supports all other components such as the engine, axle, seat, and wheels. According to **Chow [4]**, while the Go-Kart chassis serves the same purpose as a car chassis, it is simpler in design and easier to fabricate. Since Go-Karts typically do not use traditional suspension systems, the chassis must strike a balance between flexibility and rigidity. As noted by **Manigandan et al. [5]**, quoting **Walker (2005)**, the absence of suspension means the chassis must absorb minor road irregularities while still being stiff enough to withstand loads, such as the driver's weight and high cornering forces. A well-designed chassis enhances traction and reduces vibration, which contributes to smoother handling and longer frame life.

Fig:1 Chassis Side View Fig:2 Chassis front view

4.2 Engine

The engine is the power source of the Go-Kart and can be either a two-stroke or four-stroke configuration. **Mehta [6]** mentions that two-stroke engines offer a wide range of power output—from 8 hp for single-cylinder units to up to 90 hp in twin-cylinder models. In our project, we selected a **150cc Bajaj Pulsar four-stroke engine**, which provides a good balance between power, fuel efficiency, and availability.

Fig:3 Braking System Fig:4 Welding Process

4.3 Transmission System The transmission system transfers engine power to the rear wheels. It generally includes a drivetrain, sprockets, chains, and sometimes a clutch or gearbox, depending on the Go-Kart design. Unlike traditional automobiles, Go-Karts typically do not have a differential; instead, both rear wheels rotate at the same speed. According to **CIK-FIA (2010)** rules, differentials are prohibited in professional karting competitions to encourage driver skill and vehicle simplicity. Gear ratios play an essential role in determining acceleration and top speed performance.

4.4 Wheels and Tyres

The wheels and tyres used in Go-Karts are significantly smaller than those on conventional vehicles. As **Prajapati et al. [7]** explained, Go-Kart tyres are designed specifically for track conditions and are generally harder to increase grip during high-speed cornering. There are two main types:

- **Slick tyres** – Smooth and used for dry track conditions to provide maximum contact and grip.
- **Wet tyres** – Grooved to channel water and prevent hydroplaning on wet tracks.

Selecting the correct tyre type is crucial for ensuring maximum performance and safety during races.

Fig:5 wheel Assembly Fig:6 Top View of Vehicle

4.5 Chassis Materials

The materials used in Go-Kart chassis must offer a balance of strength, weldability, and cost. Most frames are constructed using **mild steel (e.g., AISI 1018)** due to its moderate carbon content, which provides good hardness and machinability without being too brittle. Other vehicle components such as brake rotors, engine mounts, and fasteners are often made of cast iron or different steel alloys depending on the required mechanical properties.

4.6 Polyvinyl Chloride (PVC)

PVC (Polyvinyl Chloride) is a widely used thermoplastic material due to its strength, affordability, and resistance to environmental degradation. Though not typically used for load-bearing parts in Go-Karts, PVC can be utilized for protective covers, signage, or design elements in non-structural areas. Rigid PVC is dense and hard, with a melting point between 100°C and 260°C depending on additives, making it suitable for various industrial and decorative applications.

4.7 Bodywork

The bodywork of a Go-Kart plays both functional and aesthetic roles. It should be lightweight, rust-resistant, and capable of protecting internal components from dust and damage. For this project, we used umbrella cloth to create a flexible, low-cost body covering. This material is waterproof, easy to shape, and lightweight, which helps reduce overall vehicle mass.

Important considerations for the bodywork include:

- ✓ Easy access to mechanical parts for maintenance.
- ✓ Rust and corrosion resistance.
- ✓ Comfortable and secure seat placement.
- ✓ Visually appealing design to enhance the kart’s look and style.

Proper placement of controls and ergonomic layout of the seat and steering wheel further improve driver comfort and operational safety.

Fig:7 Full body after assembly

Fig:8 Front wheel

5. Methods

The methodology followed in this project was structured in several systematic stages, from concept development to final testing. The focus was to develop a functional and safe Go-Kart using cost-effective materials while incorporating standard engineering practices.

When designing any system that involves human interaction especially where safety is a concern it's essential to incorporate a sufficient Factor of Safety (FOS). Since this project involves a driver-operated vehicle, protecting human life and property is a top priority. Therefore, a minimum FOS of 3.2 was chosen to ensure reliability and durability under dynamic loading conditions.

The chassis was constructed using pressurized PVC pipe, a lightweight yet reasonably strong material with a yield strength of approximately 52 MPa. During the stress analysis, the maximum stress experienced by the frame was found to be 16.25 MPa, which is well within the safety limit when compared to the material's yield strength.

The major loads considered in the FOS calculations include:

Weight of the chassis frame: **45 kg**
Mass of the engine: **8 kg**
Average driver weight: **55 kg**

5.1 Factor of Safety (FOS)

In any engineering design, especially where human safety is involved, the application of a suitable Factor of Safety (FOS) is critical. For this go-kart project, safety was a primary concern because the vehicle is intended to carry a human driver. To account for unexpected loads, material imperfections, and usage variations, a minimum FOS of 3.2 was adopted. The chassis was made using pressurized PVC pipes, a lightweight and cost-effective material. The material's yield strength is approximately 52 MPa, and stress analysis of the chassis under full load showed a maximum stress of 16.25 MPa, which is well below the yield limit and thus confirms that the selected FOS is suitable.

The following loads were considered during the design:

Weight of chassis frame: approx. 45 kg
Engine: 8 kg
Driver's weight (average): 55 kg

These weights, when combined, act on the chassis during real-time operation such as acceleration, turning, or uneven surface contact. The chosen FOS helps in handling stress peaks that may occur due to sudden man overs or impact loads during motion. Although PVC is not typically used for structural applications in automotive design, the low weight of the kart and limited speed range allow its use here in a controlled and safe environment.

5.2 Steering System – Ackermann Geometry

Ackermann steering geometry ensures that all wheels correctly follow their respective turning circles, preventing tire skidding during turns. This is essential in go-karts, especially in tight track corners.

Formula for Ackermann Angle:

$$\tan(\theta) = \frac{L}{R}$$

Where:

θ = Steering angle of the inside wheel
L = Wheelbase (distance between front and rear axles)
R = Turning radius (distance from the center of turn to the rear axle)

Also, for Ackermann geometry:

$$\cot(\delta_i) - \cot(\delta_o) = \frac{W}{L}$$

Where:

Δ_i = Inside wheel angle
Δ_0= Outside wheel angle
W = Track width (distance between the two front wheels)
L = Wheelbase

This geometry ensures precise cornering by adjusting the wheel angles appropriately.

5.3 Load Distribution on Wheels

Proper weight distribution affects handling, braking, and traction.

Static Load on Front and Rear Axle:

$$W_f = \frac{L_r}{L} \times W \quad \text{and} \quad W_r = \frac{L_f}{L} \times W$$

Where:

W_f = Load on front axle
W_r= Load on rear axle
L_f = Distance from CG to front axle

L_r = Distance from CG to rear axle
L = Wheelbase
W = Total weight of the kart

5.4 Braking Force Distribution

Braking should be balanced for efficient stopping and safety.

$$F_b = \mu \times N$$

Where:

F_b = Braking force
μ = Coefficient of friction between tire and road
N = Normal reaction (load on the wheel)

Also, braking torque is calculated by:

$$T_b = F_b \times r$$

Where:
T_b = Braking torque
r = Radius of the brake disc or wheel

5.5 Center of Gravity (CG) Height Estimation

Used for rollover analysis:

$$h = \frac{T}{2} \cdot \frac{a}{g}$$

Where:

h = Height of CG
T = Track width
a = Lateral acceleration
g = Gravitational acceleration

5.6 Designing the Frame

The frame was made out of 30mm square tubing and 25mm round tubing and 19mm round tubing for seat supports and the steering column just to make it easier to work with;

- ✓ The wheel base and track need to be approximately the same as a race kart, so 1040mm wheel base, and 680mm between the kingpins. This will provide the best handling kart as most race kart are pretty close to that size.
- ✓ The front wheels need space to move as they steer multiple bends are difficult to make so we kept the frame as simple as possible.

6. Conclusion

The design and fabrication of a low-cost electric go-kart using PVC materials were successfully completed within the scheduled time. The primary objectives of the project were met, including the development of a lightweight, affordable, and eco-friendly vehicle. By utilizing a 24V DC electric motor and replacing the conventional internal combustion engine, the design addresses issues such as fuel dependency, noise, and emissions. The go-kart was built using approximately 60% locally available materials, significantly reducing overall costs while maintaining functionality. The total cost of the project was around 308 USD. The vehicle was fully assembled and tested in the institute's workshop, demonstrating good performance and safe operation. Special attention was given to driver comfort and ergonomics, incorporating design standards such as SAE guidelines for seating. The final product not only offers ease of maintenance and assembly but also features a durable chassis and an aesthetically appealing body made from lightweight PVC and umbrella cloth. Overall, the project proves that with proper planning and design, an efficient and economical electric go-kart can be developed using simple materials and techniques, making it a viable option for student-level research, training, and recreational use.

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