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Hands-On Approach to Vehicle Design and Fabrication by Budding Engineers

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Abstract:

This paper outlines the detailed process involved in designing and constructing a budget-friendly, lightweight vehicle using commonly available materials and components. The primary objective was to enhance hands-on engineering skills by applying core concepts from mechanics, thermodynamics, material science, and manufacturing methods. The project began with initial sketches and CAD modeling, leading to the construction of a tubular frame chassis made from mild steel. A 150cc Bajaj Pulsar engine was chosen for its compactness and dependable performance, with power delivered to the rear wheels through a chain drive system. The body was fabricated using umbrella cloth, selected for its light weight and flexibility, contributing to cost reduction. Custom-built suspension, steering, and braking systems were designed and installed based on specific project needs. The entire vehicle was assembled using standard tools available in a college workshop. Upon completion, the car was tested and showed reliable performance under typical driving conditions. This paper covers every phase of the build, highlighting the obstacles encountered and the practical solutions implemented.

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

1. Introduction:

The automobile stands as a cornerstone of modern transportation, essential for commuting, business operations, and goods delivery. Engaging in the design and construction of a car provides valuable insights into the integration of key mechanical systems such as the engine, transmission, suspension, and braking. For engineering students, such projects serve as a practical platform to apply theoretical knowledge in real-world scenarios while also enhancing skills in teamwork, planning, and critical thinking. In this project, the focus was on developing a compact, cost-efficient, single-seater vehicle using locally accessible materials and basic tools. Key design priorities included safety, durability, comfort, fuel economy, and affordability. The frame was built using iron pipes for structural integrity, and umbrella cloth was used for the body to keep the weight and cost minimal. A 150cc Bajaj Pulsar engine was selected for its small size and dependable performance, making it well-suited for a lightweight design. This vehicle falls into the category of Go-Karts small, open-frame, four-wheeled racers often used for recreational and amateur racing. While inspired by the design concepts of Formula 1 cars, Go-Karts are significantly more affordable and simpler to build. Their popularity is well established in countries like the USA and is rapidly growing in India due to their thrilling performance and lower costs. These vehicles are known for their lightweight nature, ease of operation, and straightforward mechanical setup.

With growing interest among students and hobbyists, Go-Kart competitions are becoming increasingly prominent. Designing and building such vehicles demands a blend of engineering expertise and creativity. Teams must navigate various design challenges, experiment with solutions, and iteratively refine their prototypes. This project provided a hands-on opportunity to address these challenges and successfully bring a working Go-Kart model to life.

2. Literature Review:

Go-Karting has emerged as an increasingly popular segment in the automotive domain, particularly among engineering students and amateur motorsport enthusiasts. It offers a unique blend of theoretical vehicle dynamics and practical fabrication techniques, making it an excellent educational tool for budding engineers. A review of earlier studies and project reports provides valuable insights into the evolution of Go-Kart design, its fundamental concepts, and core mechanical components. According to Abdullah et al. [1], a Go-Kart is defined as a four-wheeled land vehicle in which all wheels maintain contact with the ground but are not aligned in a straight path. Typically, the front two wheels are used for steering while the rear wheels transmit the driving power. Go-Karts may or may not include a body covering, and the frame is generally constructed from welded steel tubes bent into a simple structure. The key components of a Go-Kart include the chassis, engine, steering system, wheels, and tyres—each contributing to the overall functionality and performance.

The history of Go-Karts dates back to 1956, when Art Ingels, a race car builder with Kurtis Kraft in California, developed the first known model. Initially created as child-friendly push carts, Go-Karts evolved rapidly post-World War II into a recognized category of leisure motorsport. Though rooted in the United States, the concept quickly spread to Europe and other continents, driven by the thrill and affordability these compact vehicles offer. Chauhan (2016) observed that Go-Karts are predominantly used for racing due to their light weight and simple construction. Their low ground clearance eliminates the need for conventional suspension systems, which contributes to higher acceleration by improving the power-to-weight ratio. While they may not reach the top speeds of full-sized race cars, Go-Karts generate significant torque, making them responsive and agile—perfect for short tracks and skill-based driving.

The simplicity and cost-effectiveness of Go-Karts make them ideal for educational purposes and entry-level motorsport. Student competitions such as the SAEINDIA Go-Kart Design Challenge (GKDC) have played a significant role in promoting Go-Kart development at the academic level. These competitions emphasize real-world engineering skills while addressing practical design issues like safety, comfort, structural strength, and braking reliability.

In conclusion, literature on Go-Karts reveals a clear progression from basic recreational carts to sophisticated, competition-ready machines. A deep understanding of their historical development, fundamental design principles, and recurring technical challenges is essential for creating safe, reliable, and performance-oriented Go-Karts. This knowledge base provides a strong foundation for students and engineers looking to innovate within this exciting area of vehicle design.

3. Objectives

The primary aim of this project was to design and construct a functional and cost-effective Go-Kart, while also enhancing technical knowledge and driver performance. The goals were divided into two categories: Design & Fabrication Objectives and Performance & Driving Skill Objectives**.**

1.1 Design and Fabrication Objectives

1. **Create a Lightweight yet Strong Chassis:** Develop a durable yet lightweight vehicle frame using materials that provide sufficient strength without adding excessive mass.
2. **Ensure Cost-Effective Manufacturing:** Construct the vehicle using affordable, locally sourced materials and basic fabrication techniques to keep the overall cost low.
3. **Subsystem Integration:** Effectively integrate essential vehicle systems including the power unit, steering mechanism, braking assembly, and transmission for smooth operation and mechanical harmony.
4. **Functional Testing and Evaluation:** Conduct real-world performance tests to assess the kart's handling, braking efficiency, acceleration capability, and overall reliability under various conditions.

3.2 Performance and Driver Skill Objectives

1. **Progressive Lap Time Improvement:** Practice efficient driving techniques to gradually reduce lap times and enhance overall performance on the track.
2. **Master Racing Techniques:** Develop essential race strategies such as overtaking, defensive positioning, and maneuvering through tight racing scenarios.
3. **Refine Driving Fundamentals:** Focus on improving control aspects such as braking precision, throttle management, and cornering skills to boost driving consistency.
4. **Track Familiarization:** Study and internalize the racing circuit layout to identify ideal racing lines and reduce time lost during laps.
5. **Consistency in Performance:** Aim to maintain uniform lap timings during practice and races by focusing on control and stability.
6. **Vehicle Tuning and Customization:** Experiment with mechanical adjustments, such as tire pressure, chassis alignment, and steering angles, to match driving preferences and track conditions.
7. **Strategic Driving:** Apply tactical elements such as efficient fuel usage, optimal pit stop timing, and race planning to gain an edge during competitive events.
8. **Prioritize Safety:** Adhere to track safety protocols, wear the appropriate protective gear, and regularly inspect the Go-Kart to ensure all systems are functioning properly.

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.

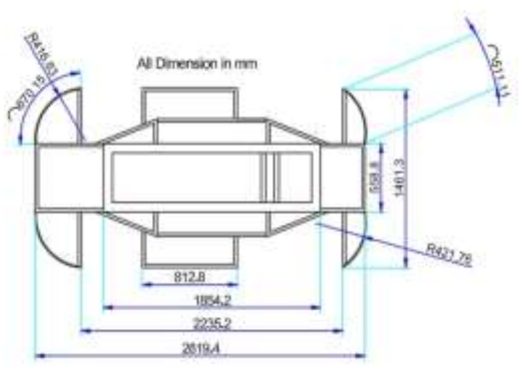

Fig:1 Chassis Top View

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 Side View

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 Transmission System

Fig:6 Transmission System

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

- **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

4.6 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.

- **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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