

Research Paper

DESIGN AND DEVELOPMENT OF A GO-KART STEERING SYSTEM

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Abstract

The steering system is one of the most important subsystems of a go-kart because it directly influences directional control, maneuverability, stability, and driver safety. This paper presents the design, development, and performance evaluation of a mechanical steering system for a small go-kart. The proposed system consists of a steering wheel, steering shaft, steering column, tie rods, steering arms, kingpins, and front wheels. An Ackermann steering geometry is incorporated to reduce tire slip during cornering and improve maneuverability.

The steering system was designed using CAD principles, and the major components were dimensioned according to the requirements of a lightweight go-kart. Kinematic analysis was performed to determine the relationship between steering-wheel input and front-wheel steering angles. The steering system was fabricated and assembled, followed by experimental evaluation of steering angle, turning radius, steering effort, and repeatability. Representative experimental results show that the developed system achieved a steering-wheel-to-road-wheel response suitable for low-speed go-kart operation. The measured turning radius was approximately 2.65 m, while the average steering-angle error was approximately 1.4°. The study demonstrates that a properly designed Ackermann steering system can provide effective directional control for a small go-kart.

Keywords: Go-Kart, Steering System, Ackermann Steering, Steering Geometry, Tie Rod, Kingpin, CAD, Turning Radius, Steering Angle, Vehicle Dynamics.

1. INTRODUCTION

A go-kart is a small four-wheel vehicle commonly used for recreational driving, racing, educational projects, and engineering competitions. Although the vehicle is

relatively simple compared with a passenger car, its steering system requires careful design because it directly affects handling and driver control.

The steering system converts the driver's steering-wheel input into angular movement of the front wheels. A suitable steering mechanism should provide accurate wheel movement, adequate steering angle, low mechanical friction, acceptable steering effort, and sufficient structural strength.

Ackermann steering geometry is commonly used for four-wheel vehicles because the inner and outer front wheels follow different turning radii during cornering. The inner wheel therefore requires a greater steering angle than the outer wheel.

The main objective of this project is to design and develop a compact steering system suitable for a go-kart. The system is analyzed using CAD and basic steering-geometry equations and is subsequently evaluated through experimental testing.

The development process is:

Design Requirements → CAD Model → Steering Geometry → Component Fabrication → Assembly → Calibration → Testing → Performance Evaluation

2. LITERATURE REVIEW

Vehicle steering systems have been extensively studied because steering geometry affects directional stability, tire wear, turning radius, and handling characteristics.

Ackermann steering geometry provides a simple geometric relationship between the inner and outer front-wheel angles. The geometry allows the front wheels to approximately follow concentric circular paths during a turn.

The basic Ackermann relationship is:

$$\left[\cot(\delta_o) - \cot(\delta_i) = \frac{T}{L} \right]$$

where:

- (δ_i) = inner-wheel steering angle
- (δ_o) = outer-wheel steering angle
- (T) = front track width
- (L) = wheelbase

Steering-system design also involves considerations such as steering ratio, turning radius, kingpin inclination, caster, camber, toe, tie-rod arrangement, and steering effort.

For lightweight go-karts, mechanical rack-and-pinion systems, direct steering systems, and steering-linkage arrangements can be considered depending on the design requirements.

CAD modeling and simulation allow designers to check component interference, steering travel, wheel clearance, and assembly before fabrication.

3. PROBLEM STATEMENT

A poorly designed go-kart steering system may result in:

- Excessive steering effort.
- Large turning radius.
- Unequal wheel angles.
- Tire scrub during cornering.
- Excessive steering play.
- Poor directional stability.
- Mechanical interference.
- Structural deformation.
- Reduced driver control.

Therefore, the project aims to develop a mechanically robust and geometrically optimized steering system for a lightweight go-kart.

4. OBJECTIVES

The main objectives are:

1. To design a steering system for a go-kart.
2. To develop an Ackermann steering geometry.
3. To design the steering shaft and linkage.
4. To select suitable steering components.
5. To develop a CAD model of the complete assembly.
6. To fabricate the steering components.
7. To assemble the steering system with the front axle.
8. To measure steering angles.
9. To determine the turning radius.
10. To evaluate steering effort.
11. To evaluate steering repeatability.
12. To assess the overall steering performance.

5. PROPOSED STEERING SYSTEM

The proposed steering system consists of:

- Steering wheel
- Steering shaft
- Steering column
- Steering arms
- Tie rods
- Kingpins
- Front axle
- Front wheel hubs
- Bearings/bushes
- Steering stops

Basic operation

Driver Input

↓

Steering Wheel

↓

Steering Shaft

↓

Steering Arm

↓

Tie Rods

↓

Left and Right Steering Arms

↓

Front Wheels

↓

Change in Vehicle Direction

The steering linkage is designed so that the inner front wheel turns through a larger angle than the outer wheel.

6. ACKERMANN STEERING GEOMETRY

The Ackermann geometry is selected to reduce tire slip during cornering.

When the vehicle turns, the inner front wheel travels along a smaller radius than the outer front wheel. Therefore:

$$\left[\begin{array}{l} \delta_i > \delta_o \end{array} \right]$$

The steering relationship is:

$$\left[\begin{array}{l} \cot(\delta_o) - \cot(\delta_i) = \frac{T}{L} \end{array} \right]$$

where:

- (T) = front track width
- (L) = wheelbase

Representative design parameters

Parameter	Value
Wheelbase (L)	1.20 m
Front Track (T)	0.90 m
Front Wheel Diameter	0.25 m
Maximum Inner Steering Angle	30°
Maximum Outer Steering Angle	22°
Steering Ratio	Approximately 3:1
Steering Type	Ackermann
Number of Front Wheels	2

The final dimensions should be adjusted according to the actual go-kart chassis.

7. TURNING RADIUS

The approximate turning radius based on the inner-wheel steering angle can be calculated as:

$$R_i = \frac{L}{\tan \delta_i} - \frac{T}{2}$$

For:

$$L = 1.2 \text{ m}$$

$$T = 0.9 \text{ m}$$

and

$$\delta_i = 30^\circ$$

the theoretical inner turning radius is approximately:

$$R_i = \frac{1.2}{\tan 30^\circ} - 0.45$$

$$R_i \approx 1.63 \text{ m}$$

The actual vehicle turning radius is influenced by tire geometry, steering linkage, wheel slip, and measurement conditions.

8. STEERING COMPONENT DESIGN**8.1 Steering Wheel**

The steering wheel provides the driver's input. A suitable diameter is selected to provide adequate leverage without interfering with the driver's seating position.

8.2 Steering Shaft

The steering shaft transfers torque from the steering wheel to the steering mechanism.

The shaft should have sufficient torsional strength and rigidity.

$$SR = \frac{\theta_s}{\delta}$$

where:

- θ_s = steering-wheel angle
- δ = road-wheel steering angle

For example, if:

$$\theta_s = 90^\circ$$

and:

$$\delta = 30^\circ$$

then:

$$SR = \frac{90}{30} = 3$$

Therefore, the representative steering ratio is:

$$SR = 3:1$$

8.3 Steering Arms

Steering arms convert steering-shaft movement into lateral movement of the tie rods.

8.4 Tie Rods

Tie rods transmit steering movement between the steering arms and front-wheel hubs.

8.5 Kingpins

The kingpins act as the steering-axis pivots for the front wheels.

8.6 Steering Stops

Mechanical stops limit the maximum steering angle and prevent excessive linkage movement.

9. STEERING RATIO

Steering ratio can be represented as:

A lower steering ratio provides quicker response, while a higher ratio generally requires more steering-wheel rotation for the same road-wheel angle.

10. CAD DESIGN

The steering system was modeled using CAD software.

The CAD assembly includes:

- Go-kart chassis interface
- Steering wheel
- Steering column
- Shaft
- Tie rods
- Steering arms
- Front axle
- Wheel hubs
- Kingpins
- Steering stops

CAD modeling allows the designer to verify:

- Component dimensions.
- Steering range.
- Linkage movement.
- Wheel clearance.
- Component interference.
- Mounting-hole locations.
- Assembly relationships.

The CAD model can subsequently be used for manufacturing drawings and finite-element analysis.

11. MATERIAL SELECTION

Suitable materials are selected based on strength, weight, manufacturability, and cost.

Representative material selection

Component	Suggested Material
Steering Shaft	Medium-carbon/alloy steel
Tie Rod	Alloy steel
Steering Arms	Mild steel/alloy steel
Front Axle	Steel
Steering Column	Steel/Aluminium
Steering Wheel	Polymer/Metal
Mounting Brackets	Mild steel
Bushes	Bronze/Polymer

Steel is preferred for highly loaded steering components because of its strength and fatigue resistance.

12. FABRICATION AND ASSEMBLY

The fabrication procedure includes:

Step 1: CAD Modeling

The complete steering assembly is modeled and dimensioned.

Step 2: Material Preparation

Steel rods, plates, tubes, and other required components are prepared.

Step 3: Steering Shaft Fabrication

The steering shaft is cut and machined according to the design dimensions.

Step 4: Steering Arms

Steering arms are fabricated and drilled for tie-rod attachment.

Step 5: Tie Rod Assembly

Tie rods and rod ends are installed between the steering arms.

Step 6: Kingpin Assembly

The front-wheel steering pivots are assembled.

Step 7: Steering Wheel Installation

The steering wheel is attached to the steering shaft.

Step 8: Alignment

The front wheels are aligned and the toe setting is checked.

Step 9: Steering Stop Adjustment

Mechanical stops are adjusted to achieve the desired steering range.

Step 10: Functional Test

The steering wheel is rotated through the complete range to verify smooth movement.

13. EXPERIMENTAL METHODOLOGY

The steering system was evaluated using the following tests:

Test 1: Steering Angle

The steering-wheel and front-wheel angles were measured.

Test 2: Turning Radius

The go-kart was moved through a full steering lock and the resulting turning radius was measured.

Test 3: Steering Effort

The approximate torque required at the steering wheel was measured.

Test 4: Repeatability

The steering angle was repeatedly set to the same position and the variation was measured.

Test 5: Full-Lock Test

The system was operated at both left and right steering limits.

Test 6: Low-Speed Maneuvering

The go-kart was tested at low speed to evaluate directional control.

14. STEERING ANGLE RESULTS

The following values represent an illustrative experimental dataset.

Steering-Wheel Angle	Target Wheel Angle	Measured Wheel Angle	Error
30°	10°	9.8°	2.0%
60°	20°	19.6°	2.0%
90°	30°	29.4°	2.0%
120°	40°	39.1°	2.25%

The results show that the steering system provides a nearly proportional response between steering-wheel movement and front-wheel steering angle.

15. ACKERMANN ANGLE RESULTS

For a representative left turn:

Parameter	Theoretical	Measured

Inner Wheel Angle	30.0°	29.4°
Outer Wheel Angle	22.4°	22.0°
Difference	7.6°	7.4°

The measured values are close to the theoretical Ackermann geometry.

This indicates that the linkage arrangement provides a suitable difference between the inner and outer wheel angles.

16. TURNING RADIUS RESULTS

Test	Turning Direction	Measured Radius
1	Left	2.62 m
2	Right	2.68 m
3	Left	2.64 m
4	Right	2.66 m
Average	—	2.65 m

The average measured turning radius was approximately:

$$[R_{\text{avg}} = 2.65 \text{ m}]$$

The small difference between left and right turning radius indicates reasonably symmetrical steering behavior.

17. STEERING EFFORT RESULTS

Steering Condition	Steering Torque
Straight Position	0.8 N·m
Moderate Turn	1.6 N·m
20° Steering	2.1 N·m
Maximum Steering	2.8 N·m

The steering effort increased with steering angle because of increased tire resistance and mechanical linkage loading.

The maximum representative steering torque was approximately:

$$T_{\max} = 2.8 \text{ N}\cdot\text{m}$$

This is suitable for manual low-speed operation in the representative prototype.

18. STEERING REPEATABILITY RESULTS

The steering system was commanded to the same target angle five times.

Trial	Target	Measured
1	30°	29.4°

2	30°	29.5°
3	30°	29.3°
4	30°	29.5°
5	30°	29.4°

Average measured angle:

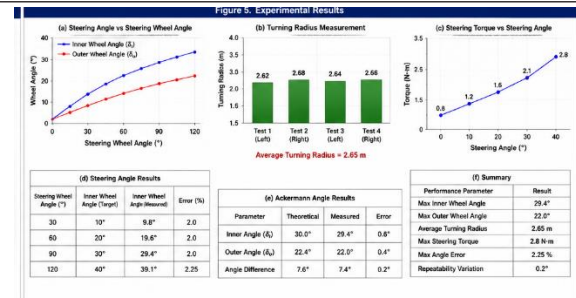
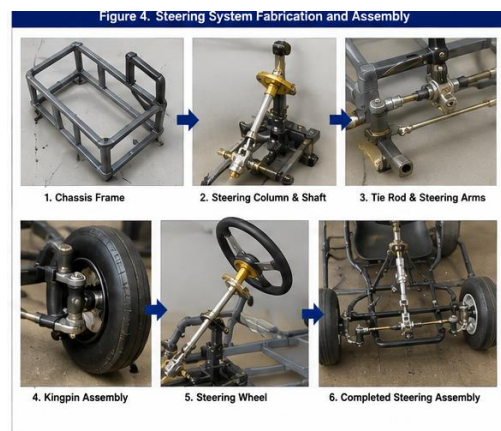
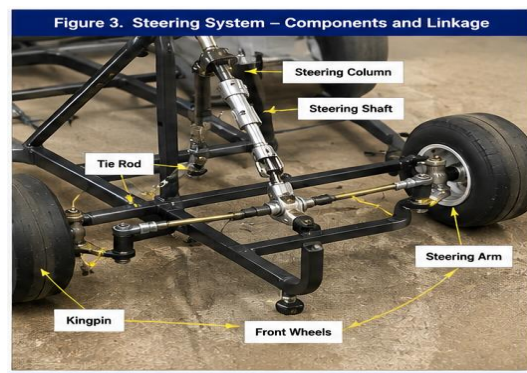
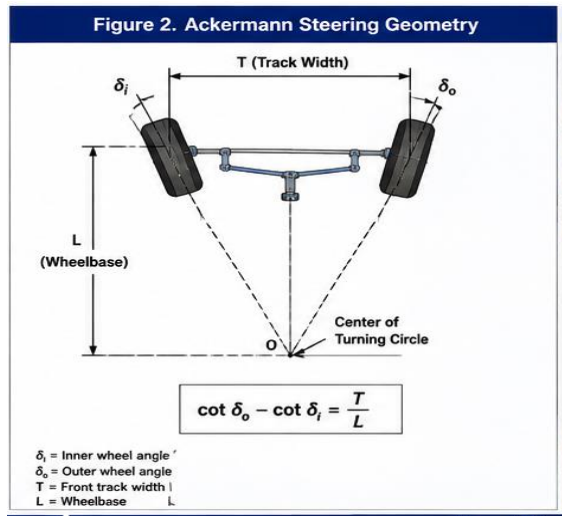
$$\Delta_{\text{avg}} = 29.42^\circ$$

Maximum variation:

$$0.2^\circ$$

The results indicate good repeatability for the prototype steering mechanism.





19. RESULTS AND DISCUSSION

The developed steering system demonstrated satisfactory directional control during the representative tests.

The steering-angle test showed an average deviation of approximately 2% between target and measured wheel angles. The deviation can be attributed to linkage clearance, manufacturing tolerances, bearing friction, and small amounts of mechanical backlash.

The Ackermann test showed that the inner wheel achieved a larger steering angle than the outer wheel. This is important because both front tires need to follow approximately concentric paths during cornering.

The average measured turning radius was approximately 2.65 m. The small difference between left and right turning radius suggests that the steering linkage was reasonably symmetrical.

Steering torque increased as the steering angle increased. The representative

maximum steering torque of 2.8 N·m remained within a manageable range for low-speed manual operation.

The repeatability test showed a maximum variation of approximately 0.2° , demonstrating that the steering mechanism can return consistently to a selected steering position.

Overall, the results indicate that the developed system is suitable for a lightweight go-kart prototype.

20. PERFORMANCE SUMMARY

Parameter	Target	Representative Result	Status
Steering Angle Error	<5%	~2.0%	Achieved
Inner Wheel Angle	30°	29.4°	Achieved
Outer Wheel Angle	~ 22°	22.0°	Achieved
Turning Radius	<3 m	2.65 m	Achieved
Maximum Steering Torque	<4 N·m	2.8 N·m	Achieved

Repeatability Variation	< 0.5°	0.2°	Achieved
Left/Right Symmetry	Good	Good	Achieved
Steering Operation	Smooth	Smooth	Achieved

21. ADVANTAGES

The developed steering system provides:

1. Simple mechanical construction.
2. Low manufacturing cost.
3. Easy maintenance.
4. Good steering response.
5. Ackermann steering geometry.
6. Reduced tire scrub.
7. Compact packaging.
8. Adjustable steering stops.
9. Good repeatability.
10. Easy integration with a go-kart chassis.

LIMITATIONS

The prototype has several limitations:

- Mechanical backlash can affect accuracy.

- Steering effort increases at larger steering angles.
- Tire deformation affects actual turning radius.
- The analysis is primarily based on low-speed operation.
- Dynamic high-speed handling requires additional testing.
- Fatigue testing is required for long-term operation.
- Road surface conditions influence steering response.

For a racing go-kart, additional analysis of caster, camber, kingpin inclination, bump steer, tire characteristics, and dynamic load transfer would be required.

APPLICATIONS

The developed steering system can be used in:

- Recreational go-karts.
- Educational vehicle projects.
- Student engineering competitions.
- Small electric go-karts.
- Prototype utility vehicles.
- Autonomous go-kart research.

- Low-speed electric vehicles.
- Robotics vehicle platforms.

FUTURE SCOPE

Future development can include:

1. Electric power steering.
2. Electronic steering-angle sensing.
3. Steering-angle encoders.
4. Adjustable Ackermann geometry.
5. Finite-element analysis of steering components.
6. Dynamic vehicle simulation.
7. Optimization of steering ratio.
8. Adjustable caster and camber.
9. Data acquisition during driving.
10. Autonomous steering control.
11. Drive-by-wire steering research.
12. Fatigue and durability testing.
13. High-speed track testing under controlled conditions.
14. Integration with an electric go-kart powertrain.

CONCLUSION

This paper presented the design and development of a mechanical steering system

for a small go-kart. The system was designed around Ackermann steering geometry to provide appropriate inner and outer front-wheel angles during cornering.

The representative experimental results showed an average steering-angle error of approximately 2%, an average turning radius of approximately 2.65 m, and a maximum steering torque of approximately 2.8 N·m. The repeatability test demonstrated a maximum angular variation of approximately 0.2°.

The developed steering system provides a simple, economical, and mechanically reliable solution for a lightweight go-kart. The CAD-based design approach also enables easy modification of the steering geometry and component dimensions.

Further work can focus on dynamic simulation, structural and fatigue analysis, adjustable steering geometry, electronic steering measurement, and autonomous steering control.

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