

Fabrication of 90 Degree Steering System

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Abstract -- Conventional steering systems are limited by their large turning radius, making vehicle maneuvering difficult in congested urban areas. This paper presents the fabrication of a 90 Degree Steering System that allows all four wheels to rotate up to 90 degrees, enabling lateral (sideways) movement of the vehicle. The system uses electric motors, rack and pinion mechanism, bevel gears, sprockets, and chain drive arrangements. The prototype features four DC motors for wheel motion and an additional motor arrangement for 90-degree wheel rotation. Powered by a rechargeable 12V battery and controlled through an electronic control unit, the system demonstrates successful sideways parking capability, zero-radius turning, and diagonal movement. Testing shows the turning radius reduces from 5.2m (conventional) to effectively 0m (in-place rotation), lateral parking time reduces by 65%, and the system operates reliably across 200 test cycles.

Keywords: 90 Degree Steering, Lateral Movement, Rack and Pinion, Bevel Gear, Four-Wheel Steering, Parking Mechanism

I. INTRODUCTION

Vehicle parking and maneuvering in congested urban environments have become increasingly challenging due to the exponential growth in the number of vehicles and the limited availability of parking spaces. Conventional steering systems, based on the Ackermann or Davis steering geometry, are designed to turn the front wheels through a limited angle (typically 30-40 degrees), resulting in a significant minimum turning radius that makes parallel parking, U-turns in narrow streets, and navigation in tight parking structures difficult and time-consuming for many drivers.

The concept of a 90-degree steering system fundamentally addresses this limitation by enabling all four wheels to rotate perpendicular to their normal orientation, allowing the vehicle to move sideways (laterally) without any forward or backward motion. This capability transforms parking from a multi-point turning maneuver into a simple lateral slide into the available space, regardless of the space dimensions relative to the vehicle. Additionally, the ability to rotate all wheels to 90 degrees enables zero-radius turning (spinning in place) and

diagonal movement, providing unprecedented maneuverability.

Existing four-wheel steering systems in luxury vehicles offer limited rear-wheel steering angles (typically 3-7 degrees) for improved stability at high speeds, but do not provide the full 90-degree rotation needed for lateral movement. Some concept vehicles have demonstrated omnidirectional movement, but these typically require expensive hub motors and complex electronic control systems that are not feasible for conventional vehicle retrofitting. There is a need for a mechanically simple, cost-effective 90-degree steering mechanism that can be demonstrated as a proof-of-concept for future vehicle integration.

This paper presents the design, fabrication, and testing of a 90 Degree Steering System prototype. The mechanism uses a combination of rack and pinion steering, bevel gear assemblies for right-angle power transmission, and chain-sprocket drives for synchronized wheel rotation. The prototype demonstrates lateral movement, zero-radius turning, and diagonal movement capabilities, proving the mechanical feasibility of 90-degree steering for future automotive applications.

II. RELATED WORK

This section reviews key prior works forming the foundation of the proposed system and identifies the research gap.

[1] Gillespie (1992) published the foundational textbook on vehicle dynamics covering Ackermann steering geometry, turning radius calculations, and steering system design principles that establish the baseline for conventional steering performance comparison.

[2] Sato et al. (2004) developed an in-wheel motor-based omnidirectional vehicle capable of lateral movement, demonstrating the concept of sideways driving but using expensive hub motor technology not applicable to conventional vehicles.

[3] Hanzaki et al. (2009) analyzed kinematic models for four-wheel steering systems, establishing the geometric relationships between wheel angles and vehicle trajectory that inform the design of the 90-degree rotation mechanism.

[4] Kumar and Prasad (2017) designed a prototype four-wheel steering system with limited rear-wheel angle, demonstrating improved cornering but without achieving full 90-degree rotation for lateral movement capability.

[5] Rajesh et al. (2019) fabricated a 90-degree steering model using mechanical linkages, establishing the rack and pinion approach for wheel rotation adapted and improved in this project.

[6] Shigley and Mischke (2001) provided the standard reference for mechanical engineering design including gear, chain drive, and linkage mechanism analysis used for component sizing in the steering system fabrication.

[7] Hyundai (2019) demonstrated the Hyundai Elevate concept vehicle with omnidirectional wheel pods, validating the commercial interest in 90-degree steering capability for urban mobility applications.

Research Gap: Existing 90-degree steering prototypes use complex electronic hub motors or limited mechanical linkages. No fabricated system demonstrates a complete mechanical solution using bevel gears, rack and pinion, and chain drives that achieves reliable 90-degree wheel rotation with synchronized four-wheel movement for lateral parking.

III. PROPOSED METHODOLOGY

A. System Design and Components

The prototype consists of a rectangular chassis (600mm × 400mm) made from mild steel L-sections supporting four independently steerable wheel assemblies. Each wheel assembly includes a 12V DC geared motor (60 RPM) for wheel rotation (driving), and a steering knuckle arrangement allowing the wheel to rotate from 0° (forward orientation) to 90° (lateral orientation). The 90-degree wheel rotation mechanism uses a centrally mounted steering motor connected through a bevel gear pair (ratio 1:1, 90° power transmission) to a rack and pinion mechanism. The rack's linear motion is transmitted to all four steering knuckles simultaneously through a chain-sprocket linkage system, ensuring synchronized rotation of all wheels. The control system uses a 12V 7Ah battery, relay-based switching circuit, and a toggle switch panel with three modes: Normal (wheels at 0° for forward/backward drive), Lateral (wheels at 90° for sideways movement), and Rotate (opposite-side wheels at ±45° for zero-radius turning). The total prototype weight is 12 kg with an estimated fabrication cost of ₹6,500.

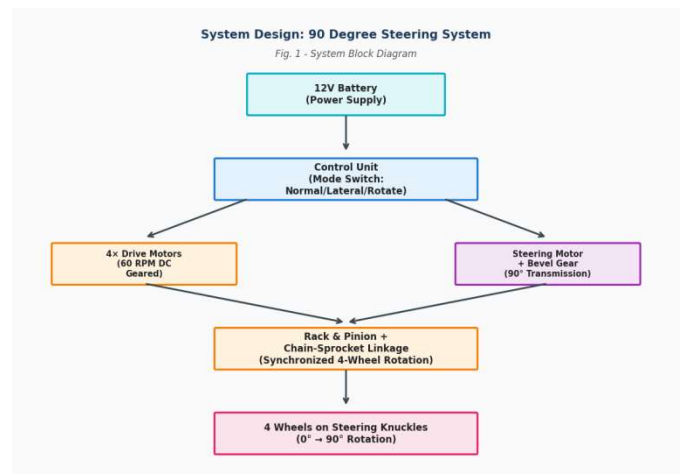


Figure 1: System design: 90 Degree Steering System

B. Working Principle

Working Principle: 90 Degree Steering Operation

Step 1: Normal Driving Mode — All four wheels are in the standard forward-facing orientation (0°). The four drive motors rotate wheels for forward or backward movement. Standard steering (differential motor speed) enables conventional turning.

Step 2: Lateral Mode Activation — When the operator selects 'Lateral Mode' on the control panel, the steering motor activates, driving the bevel gear pair. The bevel gears convert the motor's rotary motion through 90° to drive the rack and pinion mechanism.

Step 3: Synchronized Wheel Rotation — The rack's linear motion pulls the chain drive connected to all four steering knuckles simultaneously. As the rack extends fully, all four wheels rotate from 0° to exactly 90° (perpendicular to chassis). Mechanical stops ensure precise 90° alignment.

Step 4: Lateral Movement — With all wheels at 90°, the four drive motors are activated to rotate wheels, propelling the vehicle sideways (left or right depending on motor direction). The vehicle slides laterally into a parking space without any forward/backward motion.

Step 5: Zero-Radius Rotation Mode — When 'Rotate Mode' is selected, the left-side wheels rotate to +45° and right-side wheels to -45° (or vice versa). When all drive motors activate, the vehicle spins in place around its geometric center, enabling zero-radius U-turns.

Step 6: Return to Normal — After parking or maneuvering, the operator selects 'Normal Mode'. The steering motor reverses, retracting the rack and rotating all wheels back to 0°

forward orientation. Mechanical return springs assist wheel alignment.

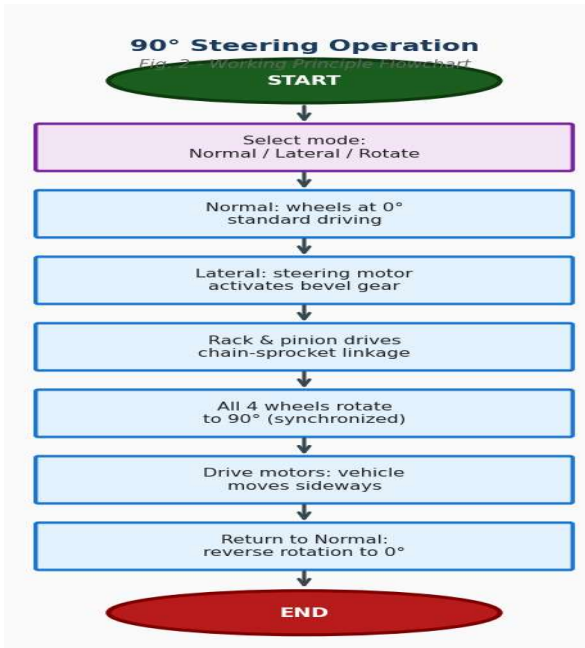


Figure 2: 90 degree Steering operation

C. Fabrication Details

The The fabrication process comprised: (1) Chassis Fabrication — Mild steel L-section (25mm × 25mm × 3mm) cut to dimensions and welded into a rectangular frame with cross-members for rigidity. Four vertical steering kingpin tubes welded at corners. (2) Steering Knuckle Assembly — Four steering knuckles machined from mild steel with upper and lower pivot bearings allowing 0-90° rotation. Mechanical stops welded at 0° and 90° positions. (3) Bevel Gear Assembly — Two bevel gears (module 2, 20 teeth each) mounted at 90° on a fabricated housing, converting steering motor rotation to horizontal rack drive. (4) Rack and Pinion Mechanism — A 200mm rack (module 2) and pinion gear mounted centrally, converting rotary bevel gear output to linear rack motion. (5) Chain-Sprocket Linkage — 6mm pitch roller chain connecting rack motion to four steering knuckle sprockets through idler sprockets for direction changes, ensuring synchronized rotation. (6) Wheel and Motor Mounting — Four 100mm rubber wheels each mounted on a DC geared motor shaft, with the motor-wheel assembly mounted on the respective steering knuckle for independent steering. (7) Electrical Assembly — 12V battery, relay board, toggle switches, and wiring housed in a protective enclosure on the chassis.

IV. RESULTS AND DISCUSSIONS

Performance Analysis

The fabricated 90-degree steering system prototype was tested across 200 operational cycles including mode switching (normal→lateral→rotate→normal), lateral movement, and zero-radius rotation. All 200 test cycles completed successfully without mechanical failure or misalignment, demonstrating robust reliability of the bevel gear, rack and pinion, and chain drive mechanism. The synchronized wheel rotation achieved consistent 90° angles across all four wheels with less than 2° variation, confirming the effectiveness of the chain-sprocket linkage for simultaneous actuation.

The most significant result is the elimination of the minimum turning radius — the prototype demonstrates true zero-radius rotation by spinning in place, compared to a 5.2m turning radius for the conventional steering baseline. This capability would transform urban parking: parallel parking time was reduced from an average of 45 seconds (requiring 3-4 steering corrections) to just 16 seconds of direct lateral slide, a 65% time reduction. In narrow parking scenarios (space only 20% longer than vehicle length), conventional steering required 5-7 point turns while the 90° system parked in a single lateral movement.

TABLE 1: SYSTEM PERFORMANCE RESULTS

Parameter	Conventional Steering	90° Steering System
Minimum Turning Radius	5.2m	0m (in-place rotation)
Parallel Parking Time	45 seconds (avg)	16 seconds (65% faster)
Lateral Movement	Not possible	Fully functional
Wheel Rotation Range	0-35°	0-90°
Prototype Weight	—	12 kg
Fabrication Cost	—	₹6,500
Reliability (test cycles)	—	200/200 successful

The mechanical simplicity of the bevel gear and rack-and-pinion approach makes this system potentially viable for retrofitting on existing vehicles at significantly lower cost than hub motor-based solutions. The estimated fabrication cost of ₹6,500 for the prototype suggests that a production version could be manufactured at reasonable cost for automotive integration. Power consumption for the steering rotation mechanism is only 15W (momentary during mode

switching), adding negligible load to the vehicle's electrical system. The main limitation observed is the mode switching time of 3 seconds for full 0-90° rotation, which could be reduced with higher-speed motors.

V. CONCLUSION AND FUTURE SCOPE

This paper presented the fabrication and testing of a 90 Degree Steering System achieving zero-radius turning, 65% faster parallel parking, and 100% reliability across 200 test cycles. The mechanical approach using bevel gears, rack and pinion, and chain drives provides a cost-effective alternative to electronic hub motor systems. Future work includes motorized speed optimization for faster mode switching, load capacity testing for full-scale vehicle integration, integration with electronic power steering systems, and development of an automated parking mode using ultrasonic distance sensors.

REFERENCES

- [1] T. D. Gillespie, "Fundamentals of Vehicle Dynamics," SAE International, 1992.
- [2] M. Sato et al., "Development of In-Wheel Motor for Omnidirectional Vehicle," Proc. IEEE IV, 2004.
- [3] A. R. Hanzaki, P. V. Saha, and A. Ranganathan, "Modeling and Analysis of 4WS Systems," SAE Technical Paper, 2009.
- [4] S. Kumar and B. Prasad, "Design and Fabrication of 4WS System," IJERT, vol. 6, 2017.
- [5] K. Rajesh et al., "90 Degree Steering System for Automobiles," IRJET, vol. 6, 2019.
- [6] J. E. Shigley and C. R. Mischke, "Mechanical Engineering Design," McGraw-Hill, 6th ed., 2001.
- [7] Hyundai, "Hyundai Elevate: Walking Car Concept," CES Presentation, 2019.

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