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Dual Mode Four Wheel Steering System

Sanu Adolphus
UG Student
Department of Mechanical Engineering
Saintgits College of Engineering, Kottayam, Kerala

Sooraj Abraham
UG Student
Department of Mechanical Engineering
Saintgits College of Engineering, Kottayam, Kerala

Justin T Martin
UG Student
Department of Mechanical Engineering
Saintgits College of Engineering, Kottayam, Kerala

Nikhil Sasikumaran Nair
UG Student
Department of Mechanical Engineering
Saintgits College of Engineering, Kottayam, Kerala

Liju Mathew Alexander
Assistant.Professor
Department of Mechanical Engineering
Saintgits College of Engineering, Kottayam, Kerala

Abstract

Two wheel steering mechanism used in common vehicles are having a high turning radius and also difficult in high speed maneuvering. This results in low stability. The four wheel steering mechanism currently used in heavy vehicles, which drives the rear wheels at a same angle as that of the front wheels may result in over steer. So this cannot be implemented in light vehicles. An innovative four wheel steering mechanism which rectifies the above mentioned drawbacks are proposed which serves as our project work. In this steering mechanism the rear wheels are not actually following the front wheels, but turns at a specific ratio. There are two modes of steering mechanism that is for low speed and high speed. At slow speeds, the rear wheels turn in opposite direction of the front wheels. At faster speeds, the rear wheels turn in the same direction as that of front wheels. This steering mechanism improves steering response, increase vehicle stability, improves control etc. In situations like low speed cornering, vehicle parking and driving in city conditions with heavy traffic in tight spaces becomes easy, this is because of rear wheel turn in opposite direction to front wheel. At high speed it increases vehicle stability while maneuvering at and lane changing.
Keywords: Steering Mechanism, Wheel Steering Mechanism, Turning Radius, Vehicle Stability

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I. Introduction

Four Wheel Steering System is employed in vehicles to achieve better maneuverability at high speeds, reducing the turning circle radius of the car and to reduce the driver's steering effort.

In most active 4 wheel steering system, the guiding computer or electronic equipment play a major role, in our project we have tried to keep the mechanism as much economical as possible. This project focuses on a mechanically feasible and innovative design involving an arduino circuit board and quadra coupler. Quadra coupler attached to steering column to sense the rotation of steering and given to arduino circuit board, the output from arduino circuit board is given to a dc motor with 2 reduction . The dc motor direct the rear wheel, by a simple chain drive.

At slow speeds rear wheels turn in direction opposite to that of front wheels. This mode is used for navigating through hilly areas and in congested city where better cornering is required for U turn and tight streets with low turning circle which can be reduced . Also more capable for parking .At High Speeds, turning the rear wheels through an angle opposite to front wheels might lead to vehicle instability and is thus unsuitable. Hence the rear wheels are turned in the same direction of front wheels in four-wheel steering systems.

A. *Four Wheel Steering System*

Four-wheel steering, 4WS, also called rear-wheel steering or all-wheel steering, provides a means to actively steer the rear wheels during turning maneuvers. It should not be confused with four-wheel drive in which all four wheels of a vehicle are powered. It improves handling and helps the vehicle make tighter turns. Production-built cars tend to under steer or, in few instances, over steer. If a car could automatically compensate for an under steer over steer problem, the driver would enjoy nearly neutral steering under varying conditions. 4WS is a serious effort on the part of automotive design engineers to provide near-neutral steering. The front wheels do most of the steering. Rear wheel turning is generally limited to half during an opposite direction turn.

When both the front and rear wheels steer toward the same direction, they are said to be in phase and this produces a kind of sideways movement of the car at low speeds. When the front and rear wheels are steered in opposite direction, this is called anti-phase, counter-phase or opposite-phase and it produces a sharper, tighter turn. This project aims at developing a 4 Wheel Steering

System which would cater to the needs of people. This system is employed to improve steering response, increase vehicle stability while maneuvering at high speed, or to decrease turning radius at low speed.

The concept is simple, rather than controlling a car solely by the angle at which the front tires meet the road the method used by wheeled vehicles since the horse-drawn carriage, four-wheel steering turns the wheels simultaneously at both ends of the car. The idea is intuitively appealing to any city driver who has ever pulled up to a too-short parking space and wished he could point all four tires toward the curband crab right in.

For starters, the rear wheels of a four-wheel-steer car do not always turn in tandem with the front wheels. Depending on the speed of the car, the rear wheels may turn in the same direction (same-side steering) as the front wheels, or in the opposite direction (counter steering). Most of the new four-wheel-steer autos are capable of both counter steering and same-side steering. In sharp, slow-speed turns, counter steering can shave a full yard off a standard sedan's turning radius. At high speeds, however, counter steering can make a car dangerously unstable, while same-side steering actually improves the ride.

The difference comes from the dynamics of high-speed motoring. When a driver traveling at highway speeds turns the wheel of a conventional, two-wheel steering car, the front tires immediately begin to pivot and the car's forward momentum generates a powerful sideways or cornering force at the front axle. The rear tires, however, have to wait until the car has actually started its turn before they begin to generate a corresponding force at the rear axle. That is why a car with two-wheel steering fishtails during lane changes; the back end is trying to catch up to the front. In extreme cases, or under slippery conditions, the rear of the car may fishtail out of control.

In a four-wheel-steer car, this high-speed sway can be damped or even eliminated through the use of same-side steering as shown in fig 1.1. When the rear wheels are turned at the same time and in the same direction as the front wheels, the back end turns with the front, and the cornering forces occur at both axles simultaneously. The car slides smoothly to the side without sway or fishtail.

B. Rear Wheel Steering

A few types of vehicle use only rear wheel steering, notably fork lift trucks, camera dollies, early pay loaders, Buckminster Fuller's Dymaxion car, and the Thrusts SC.

Rear wheel steering tends to be unstable because in turns the steering geometry changes hence decreasing the turn radius (oversteer), rather than increase it (Understeer) as shown in fig 1.2. A rear wheel steered automobile exhibits non-minimum phase behavior. It turns in the direction opposite of how it is initially steered. A rapid steering input will cause two accelerations, first in the direction that the wheel is steered, and then in the opposite direction: a "reverse response." This makes it harder to steer a rear wheel steered vehicle at high speed than a front wheel steered vehicle.

II. RELEVANCE

Nowadays all vehicles uses two wheel steering system, but the efficiency of the two wheel steering (2WS) vehicle is proven that it is still low compared to the four wheel steering (4WS) system car. So, this project is base on how to prove that the 4WS is better than 2WS in terms of turning radius and high speed lane changing.

A vehicle with higher turning radius face difficulty in parking and low speed cornering due to its higher wheelbase and track width, but the passenger prefer the vehicle to be higher wheelbase and track width as it gives good comfort while travelling.

In this scenario four wheel steering will be effective as the turning radius will be decreased for the same vehicle of higher wheelbase. In this project a benchmark vehicle is considered and four wheel steering is implemented without change in dimension of the vehicle and reduction in turning radius is achieved. For achieving reduction a mechanism is built which turns the rear wheels opposite to the front wheels.

In four wheel steering the rear wheels turn with the front wheels thus increasing the efficiency of the vehicle. The direction of steering the rear wheels relative to the front wheels depends on the operating conditions. At low speed wheel movement is pronounced, so that rear wheels are steered in the opposite direction to that of front wheels. At high speed, when steering adjustments are subtle, the front wheels and the rear wheels turn in the same direction.By changing the direction of the rear wheels there is reduction in turning radius of the vehicle which is efficient in parking, low speed cornering and high speed lane change.

III. DESIGN OF PROTOTYPE

A. Design of Chasis

For building of prototype model as in fig 4.1, the designed model is considered along with that a frame is built to support the steering, suspension and seat. The frame is designed considering the wheelbase and track width of Maruti Suzuki 800 and also it has to support for the suspension part as the suspension is welded to the frame, seat is also welded to the frame, the support structure for steering column and rack body is welded to the frame. The frame also takes the road load and load of the driver, so considering all the factors the frame is designed and developed. Table 4.1 shows the prototype dimensions and table 4.2 shows the engine specifications.

Table – 1
Prototype dimensions

Details	*Dimensions*
OVERALL LENGTH	*3335mm*
OVERALL WIDTH	*1440mm*
OVERALL HEIGHT	*1405mm*
WHEELBASE	*2175mm*
MIN.TURNING RADIUS	*4.4mm*
GROUND CLEARANCE	*170mm*

Fig. 1: Chasis design

Table – 2
Engine specifications

Type	*Single cylinder, 2 stroke petrol*
Bore/stroke	*74 mm/64 mm*
Displacement	*145 cc*
Compression ratio	*8.1*
Power	*9 hp@4400 rpm*
Torque	*18 Nm@ 2800rpm*
Oil quantity	*1.7 Ltr*
Engine weight	*28.5 kg*

B. Arduino uno

Arduino is an open-source prototyping platform based on easy-to-use hardware and software. Arduino boards shown in fig 4.2 are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. One can tell the board what to do by sending a set of instructions to the microcontroller on the board. To do so people use the Arduino programming language (based on Wiring), and the Arduino Software (IDE), based on Processing.

Over the years Arduino has been the brain of thousands of projects, from everyday objects to complex scientific instruments. A worldwide community of makers - students, hobbyists, artists, programmers, and professionals - has gathered around this open-source platform, their contributions have added up to an incredible amount of accessible knowledge that can be of great help to novices and experts alike.

Arduino was born at the Ivrea Interaction Design Institute as an easy tool for fast prototyping, aimed at students without a background in electronics and programming. As soon as it reached a wider community, the Arduino board started changing to adapt to new needs and challenges, differentiating its offer from simple 8-bit boards to products for IoT applications, wearable, 3D printing, and embedded environments. All Arduino boards are completely open-source, empowering users to build them independently and eventually adapt them to their particular needs. The software, too, is open-source, and it is growing through the contributions of users worldwide.

Fig. 2: Arduino UNO

1) *Advantages of Arduino*

- Inexpensive - Arduino boards are relatively inexpensive compared to other microcontroller platforms. The least expensive version of the Arduino module can be assembled by hand, and even the pre-assembled Arduino modules cost less than $50
- Cross-platform - The Arduino Software (IDE) runs on Windows, Macintosh OSX, and Linux operating systems. Most microcontroller systems are limited to Windows.
- Simple, clear programming environment - The Arduino Software (IDE) is easy-to-use for beginners, yet flexible enough for advanced users to take advantage of as well. For teachers, it's conveniently based on the Processing programming environment, so students learning to program in that environment will be familiar with how the Arduino IDE works.
- Open source and extensible software - The Arduino software is published as open source tools, available for extension by experienced programmers. The language can be expanded through C++ libraries, and people wanting to understand the technical details can make the leap from Arduino to the AVR C programming language on which it's based. Similarly, you can add AVR-C code directly into your Arduino programs if you want to.
- Open source and extensible hardware - The plans of the Arduino boards are published under a Creative Commons license, so experienced circuit designers can make their own version of the module, extending it and improving it. Even relatively inexperienced users can build the breadboard version of the module in order to understand how it works and save money.

C. *Rotation sensor*

Magneto resistive rotational speed sensors shown in fig 4.3 provide a simple and cost-effective rotational sensing solution. They are ready to use and include the sensor, a back-biasing magnet and an advanced signal conditioning IC, all housed in a special multi-chip package.

Fig. 4.3: Rotation sensor

The well-tried and trusted KMI1xx technology provides high robustness against large magnetic fields and high temperatures, and is very stable over temperature and life time. A choice of 3 different back-biasing magnets covers sensing of active or passive targets. Devices in the KMI15 and KMI20 families have a current output using two-wire technology, while those in the KMI16 and KMI18 families feature an open collector output, with three-wire technology.

D. Dc Motor and Battery

DC motor shown in fig 4.4 contains a combination of electric motor and worm gear reduction provides power. The worm gear reduction can multiply the torque of the motor by about 50 times, while slowing the output speed of the electric motor by 50 times as well. The output of the gear reduction operates a linkage. Table 4.3 shows the battery specifications.

Fig. 4: DC motor and Battery

Table – 3
Battery specification

Voltage	*12 v*
Capacity	*35 Ah*
Weight	*kg*

IV. DESIGN PROCESS

A. Turning Circles

The turning circle of a car is the diameter of the circle described by the outside wheels when turning on full lock. There is no hard and fast formula to calculate the turning circle but you can get close by using this:

Turning circle radius = $\frac{\text{track width}}{2} + \frac{\text{wheelbase}}{\sin(\text{average steer angle})}$ (5.1)

track width = 1215mm
wheelbase = 2175mm

1) For 2 Wheel Steering

average steer angle = 31º
Turning radius = $\frac{1215}{2} + \frac{2175}{\sin(31º)}$
= 4800mm = 4.8m

2) For 4 Wheel Steering

average steer angle = 31 º +10 º = 41 º
Turning radius = $\frac{1215}{2} + \frac{2175}{\sin(41º)}$
= 3900mm = 3.9m

3) Design of Gear

Gear Ratio, G = $\frac{T_G}{T_P}$ (5.2)

Where, T_G = Number of teeth on gear (driver) = 28
T_P = Number of teeth on pinion (driven) = 18
Pitch diameter of gear, D_G = 180 mm
Pitch diameter of pinion, D_P = 120 mm
Minimum number of teeth on pinion to avoid interference,

$T_P = \frac{2A_w}{G\left[\sqrt{1+\frac{1}{G}\left(\frac{1}{G}+2\right)\sin^2\emptyset-1}\right]}$; Where , A_w = 1 module (5.3)

Where ,
A_w = Fraction by which the standard addendum for the wheel should be multiplied
G = gear ratio

Ø = pressure angle
M = required module
Therefore, $T_p = \frac{2\times1}{10\left[\sqrt{1+\frac{1}{10}\left(\frac{1}{10}+2\right)\sin^2 22.5^\circ-1}\right]} = 13.3$
ie , $T_G = G\times T_P = 1.56\times 14 = \underline{21.64}$
$L = \frac{D_G}{2} + \frac{D_P}{2}$
$= \frac{D_G}{2} + \frac{10D_P}{2} = 5.5D_P$
Where, L= distance between the centers of gears
Distance between center of gear = 660 mm
$660 = 5.5D_P$
Therefore,
$D_P = 120$ mm
$D_P = m\times T_P$
ie , $m = \frac{D_P}{T_P} = \frac{120}{18} = \underline{6.6\text{ mm}}$

Nearest standard value of module is 6 mm from databook.
Number of teeth on each wheel on pinion , $T_P = \frac{120}{6} = 20$
And , $T_G = G\times T_P = 1.56\times 18 = 28$
<u>Necessary width of pinion</u>
We have, P = 500 N
$N_P = 1700$ rpm
$T = \frac{P\times60}{2\pi N_P} = 2652$ Nm (5.4)

Tangential load = $W_T = \frac{T}{D_P/2} = 44200$ N (5.5)
Normal load ,
$W_N = \frac{W_T}{\cos Ø(22.5^\circ)} = 47840$ (5.6)
Load on bearing of wheel,
$W_R = W_N\times\sin Ø = \underline{18308\text{ N}}$ (5.7)

V. Advantages and Disadvantages

A. *Advantages*

- The vehicle's cornering behavior becomes more stable and controllable at high speeds as well as on wet or slippery road surfaces.
- The vehicle's response to steering input becomes quicker and more precise throughout the vehicle's entire speed range.
- The vehicle's straight-line stability at high speeds is improved.
- Negative effects of road irregularities and crosswinds on the vehicle's stability are minimized.
- The vehicle is less likely to go into a spin even in situations in which the driver must make a sudden and relatively large change of direction.
- By steering the rear wheels in the direction opposite the front wheels at low speeds, the vehicles turning circle radius is greatly reduced. Therefore, vehicle maneuvering on narrow roads and during parking becomes easier.

B. *Disadvantages*

Car while turning at speed of 50kmph suddenly reduces its speed to 30kmph there is transition from in-phase to out-phase steering. Since the car is turning there is also possibility of pinion stuck between two racks inside casing. Then for that instance car will become two wheel steering but this will not have any effect on front wheels and thus will not cause any damage or accident.
Pump and Sensors should be checked regularly to avoid its failure.

VI. Conclusion

As per the focus of the project we have created an innovative 4 wheel active steering mechanism which is feasible to manufacture, easy to install and highly efficient.
This system assists in high speed lane changing and better cornering. It combats the problems faced in sharp turning. It reduces the turning circle radius of the car and gives better maneuverability and control while driving at high speeds, thus attaining neutral steering.
Due to smaller turning radius the parking and unpacking of vehicle is easily performed towards the right or left side.

Moreover components used in this system are easy to manufacture, material used is feasible, reliable and easily available in market. The system assembly is easy to install and light in weight and can be implemented in all sections of cars efficiently.

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