DESIGN AND FABRICATION OF FOUR-WHEEL STEERING AGRICULTURAL TRACTOR WITH ZERO RADIUS TURN

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1. INTRODUCTION

In an automobile the steering of the vehicle plays a major role in control of the path of motion of the vehicle. The steering systems are designed to give the best control designed for the vehicle. The vehicles are designed with steering control to the front wheels or in certain cases steering control is given to the rear wheels. Yet in any vehicle the steering control is given to only the front axle or in certain cases the rear axle. This is normally referred to as a two-wheel steering system. A two-wheel steering system employs only two out the four wheels of a light motor vehicle. We can observe that the turning radius of the vehicle increases as the vehicle becomes bigger, longer, and wider.

As the increased traffic in cities, smaller roads, and congestion, bigger the vehicle more pressure and strain the driver undergoes. This makes turning the vehicle at small corners difficult. Even when the vehicle is driven on highways the vehicle is subjected to understeer and oversteer. This effort can be reduced by even employing the rear wheels of the vehicle to provide steering action. In a general steering mechanism, the rear wheels of the vehicle do not play a significant role in the steering control of the vehicle. The rear wheels are fixed along a straight path of motion. So, employing the rear wheels to provide steering action will help to reduce the turning radius of the vehicle thereby reducing the steering effort on the driver.

The rear wheels of the vehicle can move in two phases with respect to the front wheels, in-phase and counterphase. In counter phase the rear wheels rotate in opposite direction of that of the front wheels giving a reduced turning radius to the vehicle whereas, in-phase has the rear wheels rotating in the same direction as the front wheels providing a sliding action of the vehicle. The system is called a four-wheel steering system.

In the present study, steering system is designed to have a 3-mode function, counterphase steering, in-phase steering and no steering modes. These modes are selectable depending on the driver. It helps achieve a reduction in turning radius of about 20% to 30%. This system allows the vehicle to have reduced understeer and oversteer of vehicles. The vehicle has a turning motion with reduced radius in counter-phase and sliding motion in inphase.

Four-wheel steering found its most widespread use in monster trucks, where manoeuvrability in small arenas is critical, and it is also popular in large farm vehicles and trucks. General Motors offers Delphi's Quadra steer in their consumer Silverado/Sierra and Suburban/Yukon. However, only 16,500 vehicles have been sold with this system since its introduction in 2002 through 2004. Due to this low demand, GM will not offer the technology on the 2007 update to these vehicles.

Previously, Honda had four-wheel steering as an option in their 1987-2000 Prelude, and Mazda also offered four-wheel steering on the 626 and MX6 in 1988.

A new "Active Drive" system is introduced on the 2008 version of the Renault Laguna line. It was designed as one of several measures to increase security and stability. The Active Drive should lower the effects of under steer and decrease the chances of spinning by diverting part of the G-forces generated in a turn from the front to the rear tires. At low speeds the turning circle can be tightened so parking and manoeuvring is easier.

2. OBJECTIVES

The Four-Wheel steering system offers a 21% reduction in turning radius. So, if a vehicle is is capable of making a U-turn in a 25-foot space. It allows the driver to do it in about 20 feet. A front wheel active steering function is added to rear active steer. By controlling the steering angle of all four wheels, this active steering system helps improve stability and response at high speed and helps reduce driver's steering workload at low speed. The main objectives of this project are:

1. Design of the four-wheel steering agricultural tractor with zero radius turning mechanism.
2. Fabrication of four-wheel steering agricultural tractor with zero radius turning mechanism

In a typical front wheel steering system, the rear wheels do not rotate in the direction of the curve, but in this system the rear wheels rotate in the direction of the front wheel. For turning a vehicle high turning circle radius is required, but by implementing this system the difficulty of turning circle radius is eliminated. No extra space is required to turn the vehicle.

3. METHODOLOGY

The aim of our project is to incorporate all four modes of steering mechanism in single vehicle. This can be obtained by modifying the traditional steering mechanism and using modified differential gear box in case of zero-degree radius turning. In which the vehicle rotates on the position. The principle we used for project is to making changes in steering mechanism. The changes are given below.

1. There are two motor drives connected to the rear wheels, i.e., rear wheel drive, for movement.
2. Each wheel is connected with linear actuators for easy and independent turning of the wheels in any directions.
3. Operating linear actuators in such a way that during zero degree turning radius, one side of wheel is allowed to rotate clockwise, and another is allowed to rotate counterclockwise.
4. The steering modes of vehicle can be changed by changing the position of the wheels using linear actuators.

The whole model is provided with a 12 Volt battery.

3.1 Parts used.

- DC geared motor

Fig. 4.2 DC geared motor

Wiper motors are designed for two speed operation. The motor consists of three brushes namely, common, low speed and high speed. Two of the brushes will be supplied for different mode of operation.

12v high torque low rpm electric motor

Structure	:	Synchronous Motor
Shape	:	Tubular
Phase	:	Single-phase
Protect Feature	:	Waterproof
Speed	:	High Speed
Function	:	Control
Usage	:	Car
Construction	:	Permanent magnet
Test Voltage	:	12VDC/24VDC
Power output	:	25-30W
No load Speed	:	85 ± 15 rpm
Rated Speed	:	60 ± 15 rpm
Current (No Load)	:	<5A
Rated Current (Load)	:	<15 A
Stall Current (Locked):		<28A at 12V
Rated Torque	:	30Kg.cm (2.9N.m)
Torque	:	18.5 Nm
Current	:	13 amps

- Rubber polymer wheel

Fig. 4.3 Rubber polymer wheel

Wheel size	75mm – 250mm
Wheel shape	Round & Flat
Colour option	Red
Load capacity	Upto 4000 kg

HI Polymer wheels are compression moulded and then machined giving them added strength and durability. The straight sided design of these wheels is what allows them to offer such superior load capacities. Wheel hardness ranges depend on the specific polyurethane wheel but are typically around 90-95 (+/-5) Shore A scale with a temperature range of 40° to 180°F. Polyurethane caster wheels are made of robust, long-lasting polyurethane material instead of commonly used plastic or metal. They are one of the most durable wheel options on the market and can support heavier equipment that needs smoother, more agile movements than standard caster wheels may provide.

- Screw rod

Fig. 3.3.7 Screw rod

Type	:	Threaded Rod
Diameter (mm)	:	M8
Length	:	1 m
Material	:	Stainless Steel (SS202)
Standard	:	DIN 975
Thread	:	Metric
Property Class	:	A2
Features	:	High Strength. Quality Assured. Long Service Life.

3.2 Calculations

Specifications

• 60 rpm

• 12 V

• 18 W

• Torque of motor:$\tau = P \times 60/ (2 \times 3.14 \times N)$ …(1)

$\tau = 18 \times 60/ (2 \times 3.14 \times 60) = 2.866$ Nm $= 2.866 \times 10^3$ N-mm

Torque required to rotate the wheel:

mass = 2kg wheel radius = 0.0381m

max velocity vehicle needs to move = 0.31 m/s

rpm = 90

acceleration to max velocity = 1.3m/s^2

We need 2 driving motors based on these specifications. We are assuming the force the motor would have to push would be weight.

torque = force * distance = mass * acceleration * distance
= 0.748 Nm or 0.374 Nm per motor.

3.3 3D Model

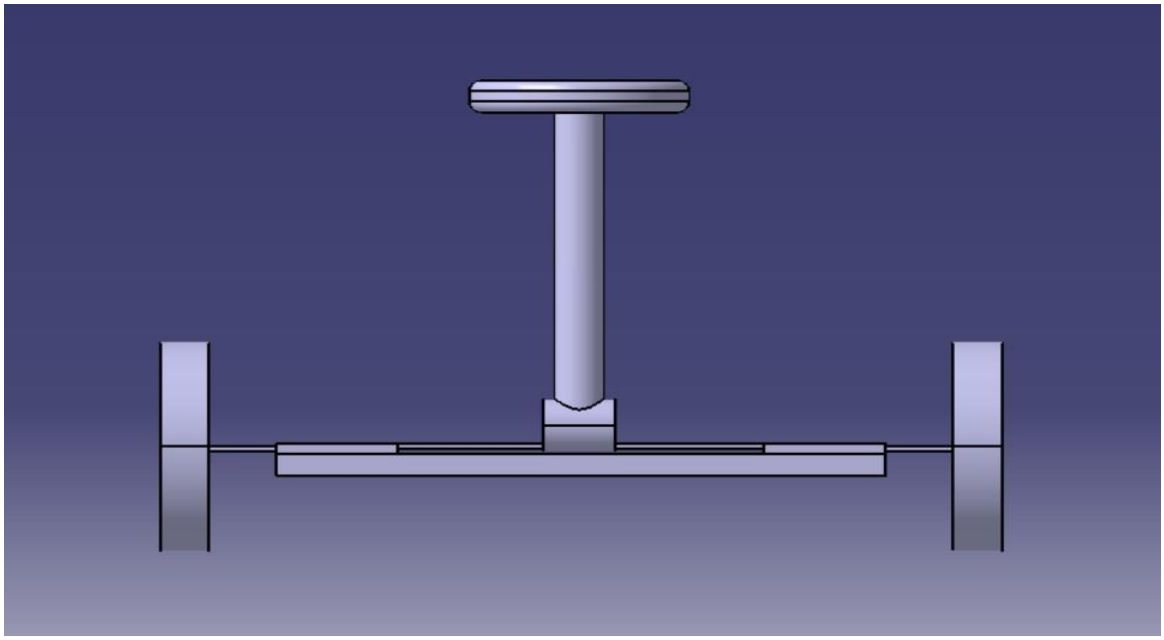

Fig. Front view of 4-wheel steering system

From the above view we can see the manual steering mechanism used for two-wheel steering. It is made by using linkage bar mechanism where the front wheels are connected in such a way that both wheels turn simultaneously.

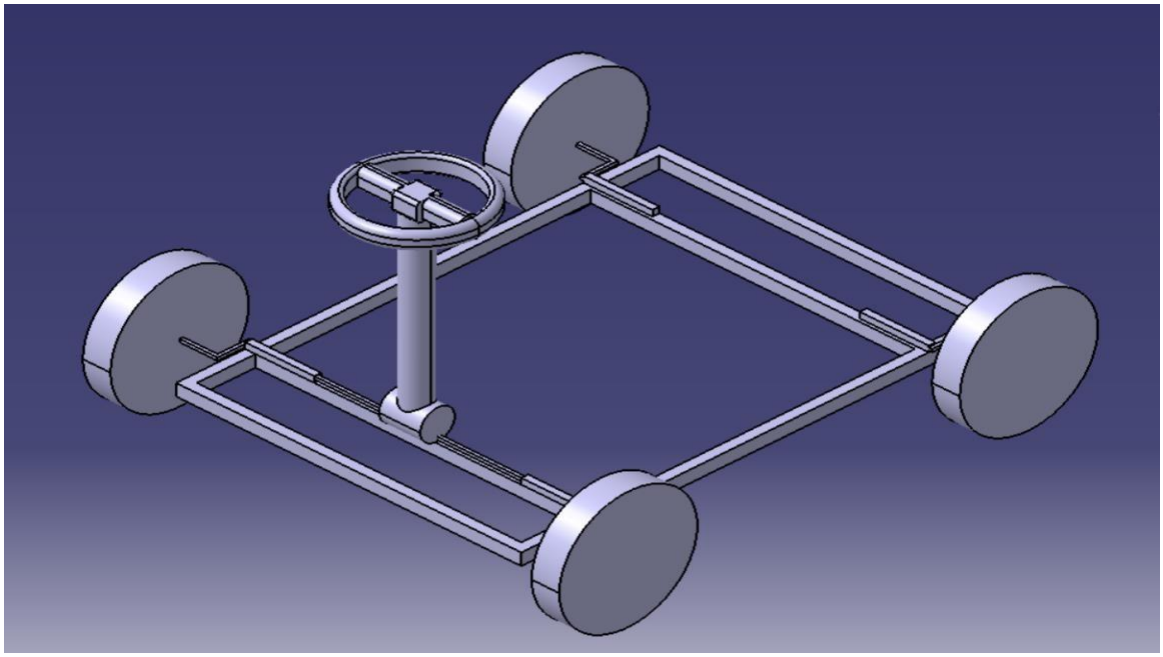

Fig. Isometric view of 4-wheel steering system

In this isometric view we can the different parts used in this project such as wheels, linkage mechanism and steering wheel.

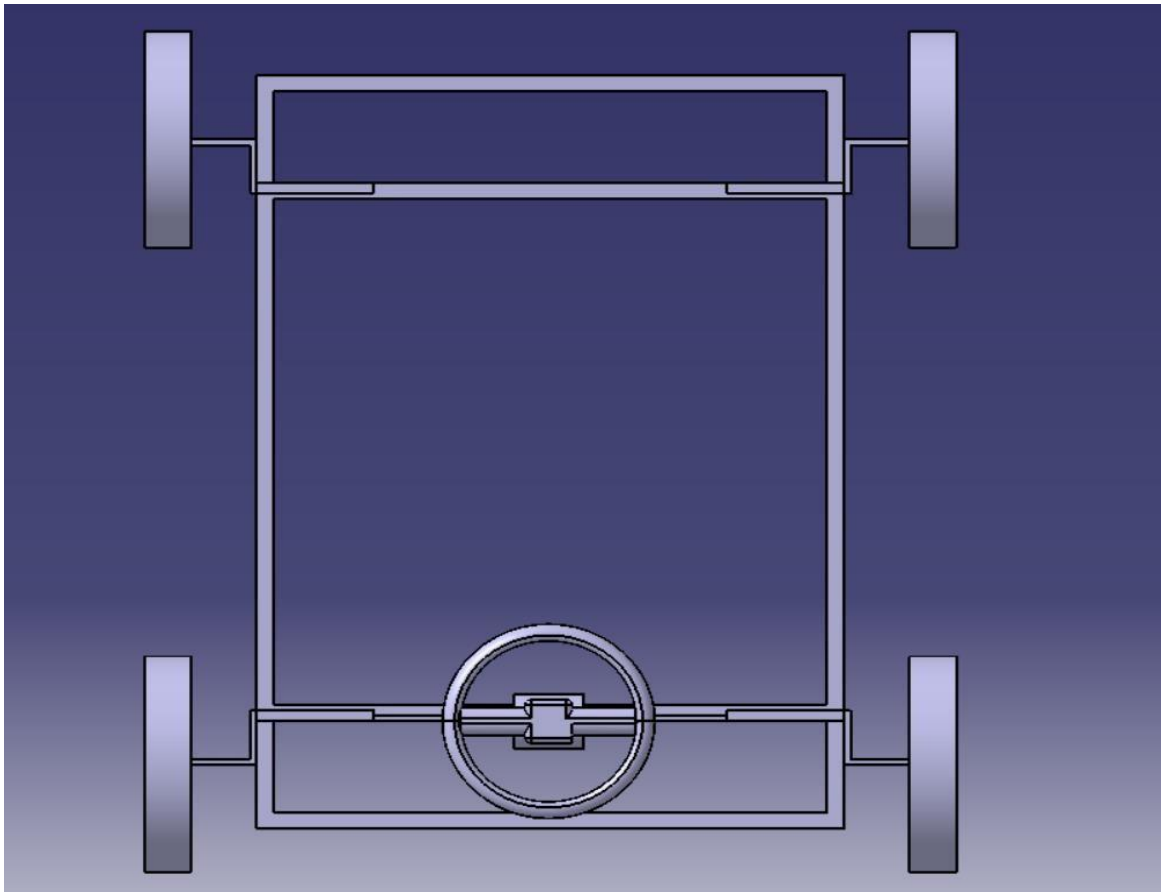

Fig. Top view of 4-wheel steering system

3.4 2D Draft

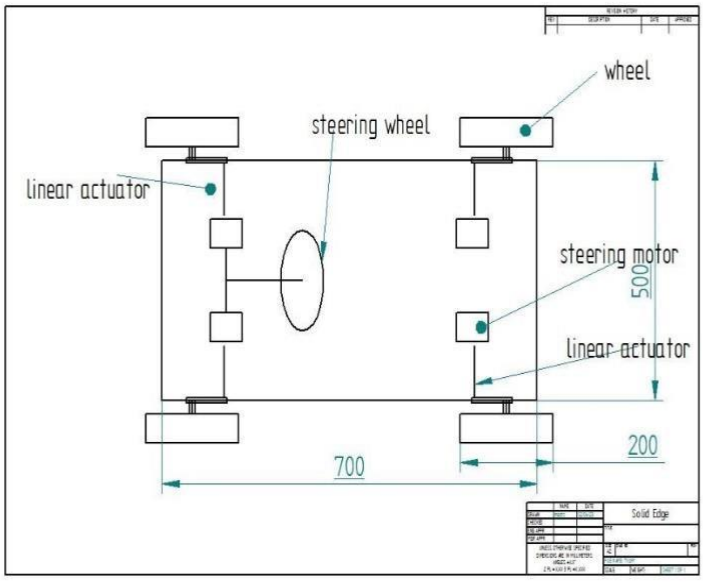

Fig. 2D draft of 4-wheel steering system

6. RESULTS AND DISCUSSION

From Ackerman Steering Mechanism

- The obtained value for Outer front wheel: 2503.9 mm
- The obtained value for Inner front wheel: 1547.5 mm

  Turning radius at Front: 2025 mm

- The obtained value for Outer rear wheel: 2215.6 mm
- The obtained value for Inner rear wheel: 1091.6 mm

  Turning radius at Rear: 1653 mm

From four-wheel steering mechanism.

- The obtained value for Outer front wheel: 2.2800 m
- The obtained value for Inner front wheel: 1.34949 m

  Turning radius at Front: 1.8147 m

- The obtained value for Outer rear wheel: 0.93960 m
- The obtained value for Inner rear wheel: 0.277 m

  Turning radius at Rear: 0.6083 m

From the above calculations and the observations from the Four-wheel steering mechanism, it is found that the turning radius of the vehicle is reduced by 34.13%.

Advantages of four-wheel steering system

1. Improved Handling: Four-wheel steering systems can greatly improve a vehicle's handling by reducing the turning radius, increasing stability and control during cornering, and providing better traction in low-grip situations.

2. Increased Manoeuvrability: Four-wheel steering systems allow for greater manoeuvrability, particularly in tight spaces such as parking lots or city streets, where the ability to turn more sharply can be extremely beneficial.

3. Independent Rear Steering: Some four-wheel steering systems can turn the rear wheels independently of the front wheels, which can further enhance handling and stability.

4. Improved Stability: Four-wheel steering can improve the stability of a vehicle during high-speed manoeuvres or sudden changes in direction, as well as reduce the risk of skidding or sliding.

5. Enhanced Safety: Four-wheel steering systems can improve safety by reducing the risk of accidents caused by oversteer or understeer, and by providing greater control and stability in emergency situations.

6. Improved Braking: Four-wheel steering can also improve braking performance by providing more stable and predictable stopping power, especially during sudden stops or emergency braking.

7. Enhanced Comfort: Four-wheel steering systems can provide a smoother and more comfortable ride by reducing the impact of bumps and road irregularities, as well as reducing the effects of body roll during cornering.

8. Better Fuel Efficiency: By reducing the turning radius and improving the vehicle's handling, four-wheel steering systems can also improve fuel efficiency by reducing the need for frequent stops and starts, and by optimizing the use of engine power.

9. Easy Parking: Four-wheel steering systems can make parking easier and less stressful by allowing drivers to manoeuvre into tight spaces with greater precision and control.

5. INNOVATION IN THE PROJECT

In a typical front wheel steering system, the rear wheels do not rotate in the direction of the curve, but in this system the rear wheels rotate in the direction of the front wheel. For turning a vehicle high turning circle radius is required, but by implementing this system the difficulty of turning circle radius is eliminated. No extra space is required to turn the vehicle. The vehicle can turn with radius almost equal to its length. Vehicle can move in any direction by this system as both front and rear wheels can rotate. This helps in manoeuvring the vehicle in tight spaces such as small fields. This design will provide better comfort and saves the time of farmers. That's why it is also the reliable for the farmers. As it is also battery-operated car thus no fuel is required. Hence it is economical to the environment. This will also reduce the cost of the tractor.

6. FUTURE SCOPE

With the 360-degree mode, the vehicle can quickly turn around at the press of a button and a blip of the throttle. Complicated three-point steering maneuvers and huge space requirements to park the vehicle are entirely phased out with this. Crab mode helps simplify the lane changing procedure. In conjunction with rear steer mode, four-wheel steering can significantly improve the vehicle handling at both high and low speeds.

Due to the better handling and easier steering capability, driver fatigue can be reduced even over long drives. The only major restriction for a vehicle to sport four-wheel steering is that it should have four or more wheels. Hence, every kind of private and public transport vehicle, be it cars, vans, buses, can benefit from this technology. Military reconnaissance and combat vehicles can benefit to a great extent from 360 mode, since the steering system can be purpose built for their application and are of immense help in navigating difficult terrain.