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Different Modes in Four Wheel Steered Multi-Utility Vehicles

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Abstract : Four wheel steering is the innovative technology in which research is going on. The front-to-rear wheel alignment plays a significant role in the directional stability of a vehicle in a good manner. Four wheel steering is the system that allows the rear wheels to turn for maneuvering, rather than just follow the front wheels. The system is employed by some vehicles to improve steering response, increase vehicle stability while maneuvering at high speed, or to decrease turning radius at low speed. In Four Wheel Steering System, the rear wheels do play an active role for steering, which can be guided at high as well as in low speeds. In this paper we made a four wheel steered vehicle for the analysis of four wheel steering systems (4WS). Apart from normal front wheel steered vehicle our designed model can work in all four modes of four wheel steering. The four modes include front wheel steering, 360 degree rotation of vehicle with in the position, parallel parking mode and shorter radius mode. 4WS is one of the devices which are used for the improvement of vehicle maneuverability and stability. Another significant finding is the effect of vehicle add-ons which showed how a multi utility vehicle can be made by giving a floor cleaning machine with it. We introduced Neodymium magnets to attract metal scraps, which helps us to clean the floor. It is expected that our different modes will be very beneficial to everyone who involved or interested in the automotive design, steering modes, analysis, performance assessment and applications of various types of four wheel steering systems.

Keywords: *Four mode steering, four wheelers, Neodymium magnets, maneuverability.*

I. INTRODUCTION

In a typical front wheel steering system, the rear wheels do not turn in the direction of the curve, and thus curb on the efficiency of the steering. Normally, this system has not been the preferred choice due to the complexity of conventional mechanical four wheel steering systems. However, a few cars like the Honda Prelude, Nissan Skyline GT-R have been available with four wheel steering systems, where the rear wheels turn by a small angle to aid the front wheels in steering. However, these systems had the rear wheels steered by only 2 or 3 degrees, as their main aim was to assist the front wheels rather than steer by themselves. With advances in technology, modern four wheel steering systems boast of fully electronic steer-by-wire systems, equal steer angles for front and rear wheels, and sensors to monitor the vehicle dynamics and adjust the steer angles in real time. Although such a complex 4WS model has not been created for production purposes, a number of experimental concepts with some of these technologies have been built and tested successfully. 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. This also simplifies the positioning of the car in situations such as parking in a confined space. Since the rear wheels are made to follow the path on the road taken by the front wheels, the rear of a 4WS car does not turn in the normal way. Therefore the risk of hitting an obstacle is greatly reduced. At high speed, when steering adjustments are subtle, the front wheels and rear wheels turn in the same direction. As a result, the car moves in a crab-like manner rather than in a curved path. This action is advantageous to the car while changing lanes on a high-speed road. The elimination of the centrifugal effect and, in consequence the reduction of body roll and cornering force on the tyre, improves the stability of the car so that control becomes easier and safer. In a 4WS system, the control of drive angle at front and rear wheels is most essential.

II. LITERATURE REVIEW

Lohith et al [1] shows that the Four-wheel steering is a serious effort on the part of automotive design engineers to provide near-neutral steering. In certain cases like low speed cornering, vehicle parking and driving in city conditions with heavy traffic in tight spaces, driving would be very difficult due to vehicle's larger wheelbase and track width. Hence the requirement of a mechanism which results in less turning radius arises and it will be achieved by implementing four wheel steering mechanism instead of regular two wheel steering. The rear wheels were drawn out of phase to the front wheels. In order to achieve this, a mechanism which consists of two bevel gears and intermediate shaft which transmit 100% torque as well turns rear wheels in out of phase was developed.

Choudhari [2] explains that a Four Wheel steering (4WS) System is also known as "Quadra Steering System". So both front as well as rear wheels can be steered according to speed of the vehicle and space available for turning. Quadra steer system will give full size vehicles greater ease while driving at low speed, and improves stability, handling and control at higher speed. Quadra steering system works in following three phases Negative phase, Neutral phase, Positive phase. It enables the car to be steered into tighter parking spaces and makes the car more stable at speed (less body roll). It makes the car more efficient and stable on cornering, easier and safer lanes change when on motorways. The steering system allows the driver to guide the moving vehicle on the road and turn it right or left as required. The main concept is that when turning the vehicle, there should not require greater efforts on the part of the driver.

Jeong [3] describes the vehicle modeling and dynamic analysis of four wheel steering system. The rear steering mechanism for the four wheel steering system vehicle was modeled and rear suspension was changed to McPherson-type forming a four wheel independent suspension system. Three different four wheel steering systems were analyzed. The first system serves a mechanical linkage between the front and rear steering mechanisms. The second and third systems used simple control logic based on the speed and yaw rate of the vehicle performance. Four wheel steering system vehicles proved dynamic results through double lane change test in a perfect way.

Sathyabalan et al [4] shows that the fabricated the four wheel steering can operate three mode operation. The project is to steer the vehicle according to the requirement. The four wheel steering is more required in critical roads and in desert roads. In this implementing three steering modes in a single vehicle and the modes can be changed as needed.

Hsien-Yu et al [5], focused on design of a power train for two-axle four-wheel-drive (4WD) electric vehicle (EV). The purpose is to improve the energy efficiency, driving stability for an Utility Vehicle (UV) that is original equipped with a 500cc internal combustion engine. The designed power train is consisted of two 5kw brushless DC motors (BLDC) with the associated motor drivers, automatic manual transmission (AMT), AMT controllers, and 288V16AH Lithium-ion battery pack. The works include power train specification design, mechanism and controller design for the clutch less AMT, optimal transmissions gear-shifting strategy design, and finally, power split strategy design for the 4WD in terms of wheel slip ratio control. To guarantee AMT gear-shifting quality, the gear-shifting maps was applied in gear change process. The power split strategy design for the 4WD EV was based on sliding mode algorithm, it was shown through numerical simulation that slip ratio on each wheel can be controlled within an optimal value in ECE40 drive pattern.

Gao et al [6] shows the kinematic models of planetary gear set and steering gear are established, based on the analysis of the transmission mechanism of angle superposition with Active Front Steering system (AFS). A controller of variable steering ratio for Active Front Steering system is designed, and virtual road tests are made in Car Maker driver vehicle- road simulation environment. The results of simulation tests validate the controller performance and the advantage of variable steering ratio function, also show that the driving comfort is improved at low speed especially, due to the Active Front Steering system alters the steering ratio according to the driving situation.

Schwab et al [7] explains that the Delft design, called VeloX (Human Power Team (2013)), is a fully-faired monocoque front-driven recumbent bicycle, with minimized air drag and maximized space for a big and strong athlete. The, front driven bicycles have the disadvantage that the front driving induces unwanted steering and that the frontal area of the bicycle cannot be reduced any further. A solution would be rear-wheel steering. A common thought is that a rear-wheel steered bicycle cannot be laterally self-stable, and therefore hard to control. One can design a rear-wheel steered bicycle which shows a stable forward speed range. Computer simulations demonstrate that the bicycle can be stabilized by adding a human controller model to the bicycle model. For a set of expected lateral perturbations (side wind perturbations) it is shown that rider steer torque stays within human bounds, both in magnitude and in frequency.

Pushkin Gautham [8] shows that Selectable All Wheel Steering is a relatively new technology that improves maneuverability in cars, trucks and trailers. All wheel steering is used for parking and low-speed maneuvers but in this type of steering system the vehicle can be steered on both, two wheels & four wheels. The "Selectable All Wheel Steering" is the modified form of AWS (All Wheel Steering).The engagement and disengagement of the four wheels steering is done as per the driver requirement. This provides the benefits of both two wheel and four wheel steer. Thus, can be used as front wheel steer in long straight runs and can be used as all wheel steer when sharp and close turns are needed. The Mechanically Operated SAWS arrangement is the most compact and cost effective systems which can be installed in an ATV without making changes to four wheel mechanism.

Deepak et al [9] carried out design and analysis of a three wheeled vehicle that has steering on both sides which is powered by hub motors. The vehicle is fabricated by using 1090mild steel for chassis, swing-arm and Wishbones (A-arms). It is determined that the turning radius of the wheel is obtained by using all wheels steering mechanism and it is relatively smaller than actual turning radius. The equivalent stress values were also determined for safe design.

Bhishikar et al[10] showed that standard 2 Wheel Steering System, the rear set of wheels are always directed forward and do not play an active role in controlling the steering, While in 4 Wheel Steering System, the rear wheels do play an active role for steering, which can be guided at high as well as low speeds. Production cars are designed to under steer and rarely do them over steer. If a car could automatically compensate for an under steer/over steer problem, the driver would enjoy nearly neutral steering under varying operating conditions. In situations like low speed cornering, vehicle parking and driving in city conditions with heavy traffic in tight spaces, driving would be very difficult due to a sedan's larger wheelbase and track width. Hence there is a requirement of a mechanism which result in less turning radius.

The requirement of a mechanism which results in less turning radius arises and it will be achieved by implementing four wheel steering mechanism instead of regular two wheel steering. The four wheel steering is more required in critical roads and in desert roads. In this implementing three steering modes in a single vehicle and the modes can be changed as needed. Four wheel steering system vehicles proved dynamic results through double lane change test in a perfect way. In situations like low speed cornering, vehicle parking and driving in city conditions with heavy traffic in tight spaces, driving would be very difficult due to a sedan's larger wheelbase and track width. Hence there is a requirement of a mechanism which result in less turning radius which is introduced in this mechanism.

III. WORKING PRINCIPLE

When the steering is steered the power is transferred to the front rack and pinion steering gear box, and a bevel gear arrangement is made to transfer the power to the rear rack and pinion steering gear box. Bevel gear is used to transmit the rotary motion perpendicularly, so the one bevel gear is introduced in the front steering rod. Other bevel gear is connected to the transfer rod. Two supports are used to support the transfer rod. Transfer rod is connected to the rear rack and pinion steering gear box. Rear rack and pinion steering gear box is fixed to the car body by bolts and nuts and the ends of the steering box are connected to the rear wheel hub where the tyres are mounted. As the steering is steered the rear wheels also turn by the arrangements made and the rear wheel turn in the opposite direction by the arrangements in the bevel gear.

First, we modeled and analysis a vehicle with four wheel steering (4WS) mechanisms. The 360 degree rotation mode of 4WS is applied by chain movement which helps in movement of wheels in the required position. The movement of wheels is in a way that the vehicle will move or turn in 360 degree. The Parallel parking mode is done by steering both front and rear wheels in same direction. When the lock nut is removed from the vehicle the steering operation is carried out in normal condition or in the front wheel drive. But when the lock nut is inserted, the other two modes can be used. When the gear arrangement is pushed to one position, the spur gears get engaged and the steering of rear wheel is ensured and is in same direction as that of the front wheels. When the gear arrangement is moved to other side, the spur gear disengages and the bevel gear gets engaged. Due to bevel gear arrangement, the rear wheel steers in opposite direction to the front wheel. This results in shorter radius mode steering. The shorter radius mode is done by turning the front and rear wheels in opposite direction.4WS vehicle proved the smooth motion of vehicle in all modes. The purpose of this System is to significantly reduce the turning radius of the vehicle, thereby improving the performance of the vehicle during competition. Many factors were taken into account when designing this system. The foremost criteria of the design were the reduction of the turning radius. superior cornering stability, Improved steering responsiveness and precision, High speed straight line stability, Notable improvement in rapid lane changing maneuvers, Relative wheel angles and their control, Smaller turning radius and tight space maneuverability at low speed, hence there is a requirement of a mechanism which result in less turning radius and it is achieved by implementing four wheel steering mechanism instead of regular two wheel steering.

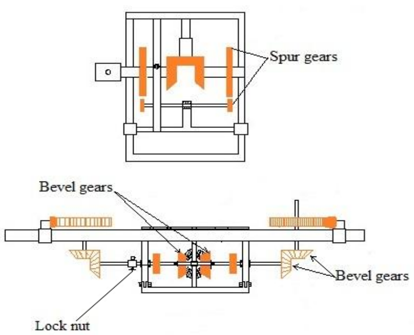

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Fig.3.1. Working of Four Modes of Steering Mechanism

In the front wheel steering, steering wheel is attached to shaft with pinion at its end, which in turn meshes with the rack. When the steering wheel is rotated, the pinion attached is rotated in the same direction, thus producing horizontal movement with rack; enabling the wheels to turn in the direction of rotation. In parallel parking mode, at first the handle is turned towards right, till the bevel gears are meshed. This enables the rotation of the shaft to be reversed. When the steering wheel is turned, the pinion rotates in the same direction and is transmitted through the bevel gears. The direction of the rotation is reversed in the central gear system and is transmitted to rear rack and pinion, enabling both front and back wheel to turn in the same direction as the rotation of steering wheel. In short radius turn mode, at first handle is turned towards left, till the spur gears are meshed. This enables the rotation of the shaft so that it is directly supplied to rear rack and pinion without reversing. When steering wheel is turned, the pinion rotates in the same direction and is transmitted through the spur gears in the central gear system and is transmitted to rear rack and pinion, enabling both front and back wheel to turn in the opposite directions. In zero degree turn mode, the handle is attached to the spur gears; which is connected to the lead screw in the rack. The handle is rotated till the rack expands to the correct size providing perfect inclination, between the wheels. The spur gears in front and back racks are rotated till correct inclination is obtained in all four wheels.

We introduced Neodymium magnets to attract metal scraps, which helps us to clean the floor. The arrangement has been provided at the front side of the vehicle. It will be very helpful in collecting unwanted parts which is smaller to remove.

The main modes available in this model are:

- Front wheel steering.
- Shorter radius turning.
- Parallel parking.
- Zero degree rotation.

3.1 Front Wheel Steering

Ackermann steering geometry is a geometric arrangement of linkages in the steering of a car or other vehicle designed to solve the problem of wheels on the inside and outside of a turn needing to trace out circles of different radii. The difficulty to arrange in practice with simple linkages, and designers draw or analyze their steering systems over the full range of steering angles. Hence, modern cars do not use pure Ackermann steering, partly because it ignores important dynamic and compliant effects, but the principle is sound for low speed maneuvers, and the right and left wheels do not turn by the same angle, be it any cornering speed.

With all the four wheels steered, the problem gets compounded, since the appropriate steering angles for all four wheels need to be calculated. It is to be noted that the variation in steering angles as a result of Ackerman geometry is progressive and not fixed; hence they have to be pre-calculated and stored by the controller. This dictates that the control of four-wheel steering systems be very precise, and consequently, complex. This is another reason why manufacturers have not preferred the use of such systems in their vehicles, even with recent advances in technology. The cost of such systems can be high, and a good amount of research & development is required upfront.

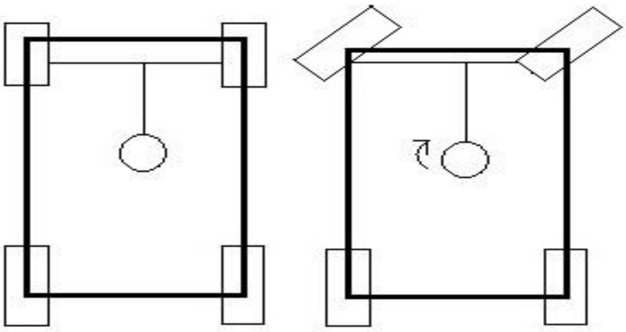

Fig.3.2.Front wheel steering

3.2. Shorter Radius Turning

To minimize the turning radius for the fixed-wheel, differential-drive configuration, the fixed-drive wheels must be located as close as possible to the geometric center of the chair. For fixed front-wheel-drive chairs, the drive wheels are moved rearward, and for fixed rear-wheel-drive chairs, the rear wheels are moved forward. Another benefit of locating the drive wheels close to the geometric center of the chair is that a larger portion of the total weight of the wheelchair is borne by the drive wheels and less by the caster wheels.

The greater the weight borne by the caster wheels, the more difficult it is to change directions when caster wheels must reverse directions and rotate through 180°. The approach, however, causes the designer to take extraordinary steps to provide stability. Typically, stability is achieved by counterbalancing the user's mass over and in front of the main drive wheels with the mass of the batteries behind the main drive wheels. It may be necessary to provide caster or sprung wheels in the rear of the chair to avoid tipping backward while accelerating forward. The addition of these extra wheels, if small, may also compromise the chair's ability to climb low obstacles.

An alternate approach to minimizing the turning radius is to steer all four wheels; this avoids the problems associated with caster wheels, yet retains minimum turning radius and maximizes stability. Added benefits of four-wheel steering are the tracking of front and rear wheels along the same path and enhanced obstacle climbing capability.

The challenge in designing a mechanical four-wheel steering mechanism is to design a device with the ability to turn each wheel through 180° while minimizing Ackerman errors (misalignment of the wheels). Ackerman steering linkages, such as those used in automobiles, owe their simple design to the relatively small turning angles required by that type of vehicle. For highly maneuverable wheelchairs, the range of steering angle is much greater, and the wheels must maintain proper alignment over that entire range to avoid undesirable scrubbing when the wheelchair moves. Scrubbing results in excessive tire wear, wrinkling of carpets, and/or undesirable tire noise.

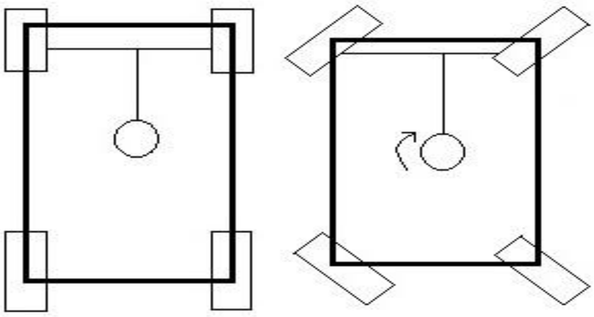

Fig.3.3.Shorter radius turning

3.3. Parallel Parking

Zero steer can be significantly easy for the parking process, due to its extremely short turning footprint. This is exemplified by the parallel parking scenario, which is common in foreign countries and is pretty relevant to our cities. Here, a car has to park between two other cars parked on the service lane. This maneuver requires a three-way movement of the vehicle and consequently heavy steering inputs. Moreover, to successfully park the vehicle without incurring any damage, at least 1.75 times the length of the car must be available for parking for a two-wheel steered car.

The car requires just about the same length as itself to park in the spot in the case of parallel parking. The vehicle will slide to the parking line at a specific angle to the wheels. Also the rear wheels will be parallel to the front wheels.

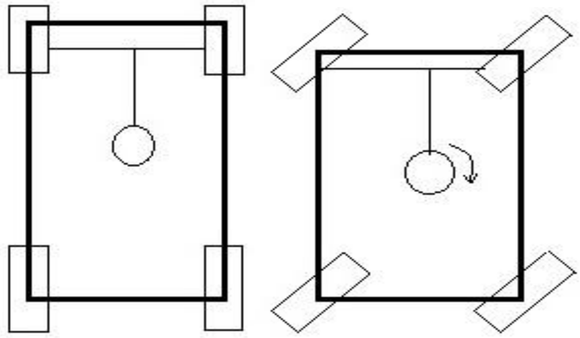

Fig.3.4.Parallel Parking

3.4. Zero Degree Rotation

This vehicle has all the four modes of steering described above, though it sports a truly complex drive-train and steering layout with two transfer cases to drive the left and right wheels separately. The four wheels have fully independent steering and need to turn in an unconventional direction to ensure that the vehicle turns around on its own axis. Such a system requires precise calculation to make certain that all three steering modes function perfectly.

The 360 degree rotation mode of 4WS is applied by chain movement which helps in movement of wheels in the required position. The movement of wheels are in a way that the vehicle will move or turn in 360 degree.

Also since the 360 degree mode does not require steering inputs the driver can virtually park the vehicle without even touching the steering wheel. All he has to do give throttle and brake inputs and even they can be automated in modern cars. Hence such a system can even lead to vehicles that can drive and park by themselves.

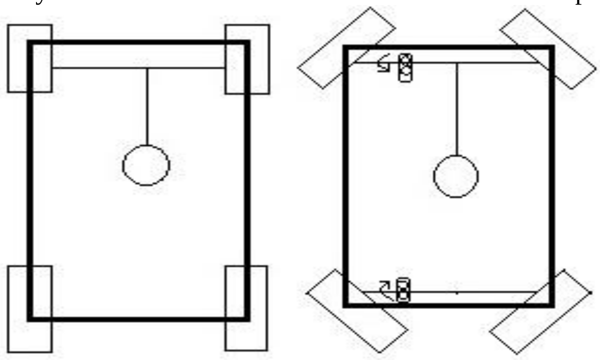

Fig.3.5. Zero Degree Rotation

IV. FIGURES

Fig.4.1.Manufactured model of four wheel steering system.

Fig.4.2. Mechanism of four wheel steering system

V. CONCLUSION

An innovative feature of this steering linkage design is its ability to drive all four (or two) wheels using a single steering actuator. Its successful implementation will allow for the development of a four-wheel, steered power base with maximum maneuverability, uncompromised static stability, front- and rear-wheel tracking, and optimum obstacle climbing capability.

Thus the four-wheel steering system has got cornering capability, steering response, straight-line stability, lane changing and low-speed maneuverability. Even though it is advantageous over the conventional two-wheel steering system, 4WS is complex and expensive. Currently the cost of a vehicle with four wheel steering is more than that for a vehicle with the conventional two wheel steering. Four wheel steering is growing in popularity and it is likely to come in more and more new vehicles. As the systems become more commonplace the cost of four wheel steering will drop.

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