Four wheel steered multi-utility vehicles-Review

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Abstract — Four wheel steering is the innovative technology in which research is ongoing. The front-to-rear wheel alignment plays a significant role in the directional stability of a vehicle. Four wheel steering is a system that allows the rear wheels to turn for maneuvering, rather than just follow the front wheels. It is a system employed by some vehicles to improve steering response, increase vehicle stability while maneuvering at high speed, or to decrease turning radius at low speed. This study dealt with reviewing four wheel steering systems in different aspects. In this context, four wheel steering technology along with its historical development was briefly given first. Next, a comprehensive review of studies conducted on them were classified and presented in tables. Four wheel steering modes were then modeled for performance evaluation purposes by using chassis structure and their modes of steering methods. Finally, the results obtained were discussed. It is expected that this comprehensive review will be very beneficial to everyone involved or interested in the automotive design, steering modes, analysis, performance assessment and applications of various types of four wheel steering systems.

Index Terms— Automobile, Four wheel steering, maneuverability, Review, multi-utility vehicles, stability, turning radius.

1 INTRODUCTION

Four wheel steering is a method developed in automobile industry for the effective turning of the vehicle and to increase the maneuverability. 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. In four wheels 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 [25].

The manufacturing sector, as a major driver for resource consumption and environmental pollution, could contribute to sustainability, due to a considerable untapped improvement potential. Nevertheless, producing companies are still hesitant to revise their activities towards resource efficiency and social responsibility [8].

The study focuses on a great alternative for transportation that does not harm the environment and also provides the user with health benefits. The Human Powered Vehicle (HPV) is a pedal powered mode of transportations therefore its success is measured by the effective transfer of pedal power to forward motion. Mechanical power losses will not be considered in this study. Evidence suggests that despite low speeds aerodynamic drag has a significant effect on average speed and rider fatigue. The aerodynamics of the vehicle are sometimes more important than the mechanical aspects of the vehicle [3].

A lot of studies about the active steering system are carried out all over the world. But most of the studies focus on the stability of vehicle, which apply AFS.As a basic function of active steering system, the driver will experience the variable steering gear ratio function at first, and perceive the improvement of steering portability. AFS enables continuous and situation-dependent variation of the steering ratio according to the vehicle's motion state; therefore AFS improve the maneuverability of the vehicle at low speed and the stability at high speed. The performances of stability improvement with active steering system depend upon the quality of variation of the steering ratio to a certain extent [15].

The steering system must also allow the driver to have some road feel (feedback through the steering wheel about road surface conditions). The steering system must help maintain proper tire-to-road contact. For maximum tire life, the steering system should maintain the proper angle between the tires both during turns and straight-ahead driving. The driver should be able to turn the vehicle with little effort, but not so easily that it is hard to control [26].

This project focuses on a mechanically feasible & innovative design involving a double rack and pinion system for rear wheels enclosed within a casing, connected to the steering column by a combination of a bevel gear assembly & telescopic shaft. The movement of the rear wheels is done by the movement of the rear pinions which in turn move the newly designed spindle to achieve the required movement of the rear wheels [23].

The main objectives in doing the present study are:

(i) To review studies conducted on Four wheel steering systems taking into consideration the analysis that have been made (theoretical–experimental, designing) and the utilization

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of the software (solid works , pro e),
(ii) To present a structural model for four wheel steering based on calculations including different parameters, such as, steering angle of the vehicle, Load on front axle, weight of car, turning radius.

2 A BRIEF DESCRIPTION ON FOUR WHEEL TECHNOLOGY

In 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 [23].

The production cars are designed to under steer and rarely do them over seer. When a car could automatically compensate for an under steer/over steer problem, the driver would enjoy nearly neutral steering under varying operating conditions. Four-wheel steering is a serious effort on the part of automotive design engineers to provide near-neutral steering. In situations like low speed cornering, vehicle parking and driving in city conditions with heavy traffic in tight spaces, driving was very difficult due to vehicle's larger wheelbase and track width, 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 [24].The Figure.1 illustrates different modes in Four Wheel Steering mechanism.

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 [23]. 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 is not been the preferred choice due to 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 an 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.

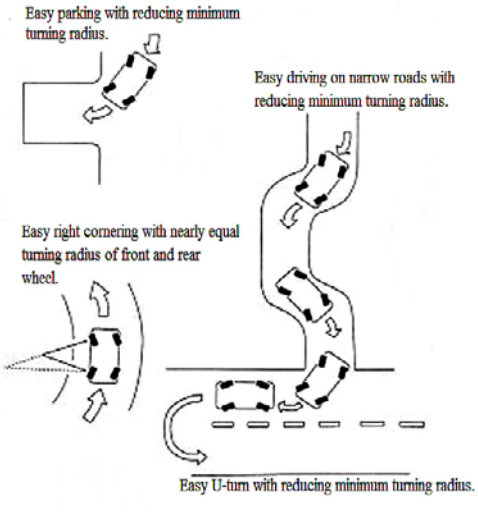

Figure.1 Illustrates Different modes in Four Wheel Steering mechanism

The idea behind four-wheel steering is that a vehicle requires less driver input for any steering maneuver if all four wheels are steering the vehicle. As with two wheel- steer vehicles, tire grip holds the four wheels on the road. However, when the driver turns the wheel slightly, all four wheels react to the steering input, causing slip angles to form at all four wheels. The entire vehicle moves in one direction rather than the rear half attempting to catch up to the front. There is also less sway when the wheels are turned back to a straight-ahead position. The vehicle responds more quickly to steering input because rear wheel lag is eliminated. 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 four wheel steering 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 the rear wheels turn in the same direction. As a result the vehicle moves in a crab like manner rather than in a curved path. This action is advantageous to the vehicle 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 tire, improves the stability of the car so that control becomes easier and safer.

3 A BRIEF HISTORICAL DEVELOPMENT OF FOUR WHEEL STEERING AND CHASSIS

General Motors 2002 GMC Sierra Denali was the first pickup to be equipped with four wheels steering, using a system that GM calls Quadrasteer. GM's Quadrasteer features. The Quadrasteer steering system offers a 21% reduction in turning

radius. So if a vehicle is capable of making a U-turn in a 25-foot space, Quadrasteer allows the driver to do it in about 20 feet [26].
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 an 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 four wheel steering model has not been created for production purposes, a number of experimental concepts with some of these technologies have been built and tested successfully [24].

Three different types of light weight design were considered. They are the space frame type, the pressed aluminum type and the monocoque design. The space frame type is commonly used in race car due to its rigidity and ease of construction. Circular or square tubes are joined together to form a lattice structure. The pressed aluminum type requires intensive forming and welding of aluminum sections. It is mainly used in high performance sports cars. Monocoque chassis differ from the other two by supporting the structural loads using external skin rather than internal member it is usually made from carbon fiber and constructed in one piece without any joints [7].

4 REVIEWING STUDIES CONDUCTED

Alam et al, [21] designed and develop human powered vehicles (HPVs) that require energy conservation, endurance and reliability The key areas with interest of Human Powered Vehicles (HPVs) are the significance of aerodynamic design and ways to improve overall aerodynamics key result was the importance of fairings, where travel could require significantly less effort as the faired vehicle tested provided only a quarter of the aerodynamic hindrance of any of the unfaired vehicles. Another significant finding is the effect of vehicle add-ons which showed how some apparently small components could have a relatively large negative impact on drag. The Human Powered Vehicle (HPV) is a pedal powered mode of transportations therefore its success is measured by the effective transfer of pedal power to forward motion.

Deepak et al, [22] 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.

Pushkin Gautham, [23] described about 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

Bhishikar et al, [24] 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.

Lohith et al, [25] showed production cars are designed to under steer and rarely do they over seer. When a car could automatically compensate for an under steer/over steer problem, the driver would enjoy nearly neutral steering under varying operating conditions. Four-wheel steering is a serious effort on the part of automotive design engineers to provide near-neutral steering. In situations like low speed cornering, vehicle parking and driving in city conditions with heavy traffic in tight spaces, driving was very difficult due to vehicle's larger wheelbase and track width, 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.

M Renjith Kumar, [26] showed the conventional floor cleaning machines is most widely used in airport platforms, railway platforms, hospitals, bus stands, and malls and in many other commercial places needed an electrical energy for its operation and not user friendly. In India, especially in summer, there is power crisis and most of the floor cleaning machine is not used effectively due to this problem, particularly in bus stands. Hence it is a need to develop low cost, user friendly floor cleaning machine. An effort has been made to develop a manually operated floor cleaning machine so that it can be an alternative for conventional floor cleaning machines. The modeling and analysis of the floor cleaning machine were done using suitable commercially available software. The conventionally used materials were used for the components of floor cleaning machine. From the finite element analysis, the stress level in the manually operated floor cleaning machine is

within the safe limit.

Bella et al, [1] explained about Collision warning and collision avoidance systems are emerging automotive safety technologies that assists drivers in avoiding rear-end collisions. Their function is to allow the driver enough time to avoid the crash and yet avoid annoying the driver with alerts perceived as occurring too early or unnecessary. By analyzing the driver's behavior effective driver assistance systems can be readily accepted by the driver. The data recorded during the tests were analyzed to assess the safety distances required by the driver during a car following situation.

Alam et al, [3] told about on road and wind-tunnel aerodynamic study of human powered vehicle. The study shows that aerodynamic efficiency of vehicle largely depends on external shape especially the extrusion, gaps and bumps

Schwab et al, [4] explained about Delft design, called VeloX (Human Power Team (2013)), are 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

Saeed Abu, [5] showed the operation of the brakes the behavior of the brake fluid in the brake piping is one element that has a large effect on feel and on transient pressure characteristics. The effect of fitting a brake pipe with different inner diameters to each wheel at the rear axle on the brake performance is done. The improvements seen in the power and dynamic performance of vehicles in recent years have made the enhancement of braking performance an important issue. Attaining better braking performance requires improvements in the characteristics of the various elements of the brake system as well as optimization of the overall system. The distribution of the brake fluid pressure between axle wheels is one element that has a large effect on braking performance and vehicle dynamic behavior during braking.

Hanif Mat et al, [7] showed the 'Eco-Challenge' race cars are built for fuel efficiency which means they must be lightweight and have low frictional resistance. They are still subjected to normal car loading such as engine and driver weight, acceleration, braking and cornering forces. The challenge is to develop a lightweight chassis that can safely withstand the required loads. The chassis must also be able to protect the driver in the event of crash. A steel space frame was chosen for the design since it is the most effective and cost efficient structure and commonly used for single seated car. FEA was used to determine the strength and rigidity of the chassis subjected to the required loads

Buchert et al, [8] facilitate the transition towards sustainable manufacturing, current practices and mechanisms for value creation need to be reconsidered along the whole product lifecycle. A multi-disciplinary research project is presented that focuses on the development of a sustainable pedal electric cycle from a first idea to a ready-to-use prototype. The results of the project show how different scientific approaches for bottom-up improvement can be applied together in a concrete case. A holistic view on the product lifecycle proved as a meaningful framework for that purpose.

Nor et al, [9] showed experimental study which is very important in order to verify the both velocity of DC motors with and without control the Pulse Width Modulation (PWM) for DC motors which control the velocities of left and right wheels of the mobile robot. Before any navigation control algorithm can be developed for navigate the mobile robot move in straight line to the stable target, both wheels should be set to move with the same velocity. From these preliminary experiments, we found that the PWM for left DC motor must be set higher than PWM for the right DC motor in order to achieve the least different velocity of both wheel. These PWMs setting for both DC motors then tested with a simple proportional control algorithm to verify effectiveness of selected PWM value for both DC motors in mission to navigate the mobile robot to the stable-target.

Zhao et al, [10] research the dynamic characteristic when the articulated vehicle accelerates, brakes and steers, it is necessary to analyze the force of the front and the rear car body and establish the steering dynamic mathematical model and simulation model when the articulated vehicle is in the heeled status. Articulated vehicle refers to the engineering vehicles that the front frame and the rear frame are connected by hinge joint and swinging rings. Articulated vehicle becomes the indispensable equipments of mining machinery and agricultural engineering because it has maneuverable, flexible, multifunctional and economic superiority. The dynamic characteristic is very important for the articulated Vehicle when the vehicle accelerates, brakes and steers. Articulated vehicles have lateral dynamic characteristic. The rollover is very dangerous and even can threaten the operator. The rolling instability is caused by many factors, such as hang, tires, human factors, weight and size, but the most important factor is the rollover due to the uneven road. Therefore, to describe the vehicle roll behavior more comprehensively and more accurately, it is necessary to rely on more perfect car model to simulate the roll response.

Hsien-Yu et al, [20] 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

Li et al, [11] showed the Wastes coming from electrical and electronic equipment (EEE) known as e-waste are a major concern because of its alarming increase as well as the hazardous substances within them that could cause harm on humans and the environment if not properly treated. In developing countries, e-waste is collected and recycled by the Informal waste sector (IWS) who neither have the proper training nor the proper equipment/facility. This makes reverse logistics of e-waste and the integration of the IWS to the formal waste sector necessary to minimize the mentioned negative effects.

Hassan et al, [12] described Electric power assisted steering system (EPAS) System can gradually replace the conventional steering system in modern cars. The main advantage of EPAS system is the ability to minimise energy consumption. The implementation of GA-PID algorithm, to realise the potential of energy reduction comparing to conventional PID method. A brushes DC motor is mounted on the steering column to provide an assist torque to the driver.

Chu et al, [14] coordinated control system is proposed to improve vehicle handling and stability by coordinating control of Electronic Stability Program (ESP) and Active Front Steering (AFS). The performance of the integrated control system is evaluated by Computer simulations at two different running condition, we compared the performance of the integrated system with other situations such as only AFS control, only ESP control and no control. The results show that the method proposed in this paper is able to improve the driving dynamics and steering stability of the vehicle effectively.

Gao et al, [15] showed 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.

Santos et al, [16] showed the techniques used in surface finish machining of gears, the honing process has been highlighted due to high efficiency in the finishing of hardened gears and ease of adjusting the involutes profile and incident angle in the counter-part. The gear honing process is used to eliminate errors that appears after the heat treatment on the tooth surface and. Although the material and cutting speed of the tool are similar to the grinding process, honing the process simulates true cinematic movement of the mesh gear, which provides a better surface roughness compared to the Hobbing process. Consequently, it is hard to correct anomalies in the gear teeth. This process has been used to improve the mechanism´s hydraulic steering pinion / rack system. Thus, it can be concluded that this process provides an excellent surface finish of the sprockets having a direct impact on the returned vehicle steering system.

Ossama Mokhiamar, [17] introduced control design concept for an optimum distribution of longitudinal and lateral forces of the four tires of a towing vehicle. The mean objectives of the control system were to stabilize the motion of an articulated vehicle utilizing the tires entire ability in both longitudinal and lateral directions as well as to make the handling characteristics of an articulated vehicle similar to those of a single one. The sliding control law based on vehicle planar equations of motion is used to derive the control laws. The system is evaluated under severe driving conditions and compared with the results of integrated control systems.

Chen et al, [18] showed Electric Power Steering (EPS) is a full electric system, which reduces the amount of steering effort by directly applying the output from an electric motor to the steering system. This develops EPS boost curve embody into the assist characteristics which improves steer portability and stability. A model for the EPS system has been established, including full vehicle mechanical system, EPS mechanical system, and EPS electric control system. Based on this model, a straight line boost curve was designed and evaluated in this environment to improve the performance of EPS system. Results showed that EPS system with the designed boost curve reduced reacting time and overshoot value, thus ensure the dynamic reaction and stability.

Guirong et al, [19] showed pure electric vehicle has become the representative of new energy source auto because of its low level of environmental pollution, noise, high efficiency, availability of multiple energy resources, and ability of energy feedback. Pure electric vehicle is driven by motor, with no reduction gears in the scope of fixed torque and fixed power. It can also generate torque in the low speed scope, and can work under the way of fixed power using field-weakening control in the high speed scope. The advantages and disadvantages of traditional drive mode, motor-driving axle combined drive mode, motor-driving axle integrated drive mode, and wheel-hub motor drive mode are favourable to us. The electric wheel driving vehicle gradually becomes a new direction of pure electric vehicle relying on its great advantage in the 4 driving modes.

5 CONCLUSION

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. There are some points to describe this topic from existing front axle steering system-

- 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 manoeuvrability at low speed.

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