

DESIGN AND FABRICATION OF FOUR MODE IN FOUR WHEELER STEERING MECHANISM

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Engineering degree in Mechanical Engineering

By

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**DEPARTMENT OF MECHANICAL ENGINEERING
SCHOOL OF MECHANICAL ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade “A” by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of Gogul Abishak R. S (Reg .No.38150032), John Sherwin Abishek J (Reg.No.38150044) who carried out the project entitled **"DESIGN AND FABRICATION OF FOUR MODE IN FOUR WHEELER STEERING MECHANISM"** under our supervision from February 2022 to April 2022.

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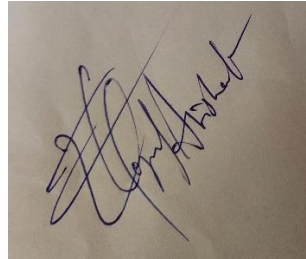
DECLARATION

We Gogul Abishak R S (Reg.No.38150032) and John Sherwin Abhishek (Reg.No.38150044) hereby declare that the Project Report entitled “**DESIGN AND FABRICATION OF FOUR MODE IN FOUR WHEELER STEERING MECHANISM**” done by us under the guidance of **Dr.B.Kanimozhi M.E.,Ph.D.**, is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

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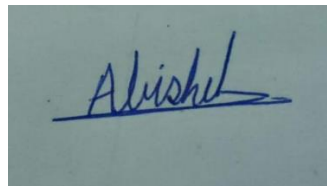
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ABSTRACT

Nowadays, the every vehicle existed mostly still using the two wheel steering system to control the movement of the vehicle whether it is front wheel drive, rear wheel drive or all-wheel drive. But due to the awareness of safety, four wheel steering vehicles are being used increasingly due to high performance and stability that they bring to the vehicles. In this report, the performance of four wheels steered vehicle model is considered which is optimally controlled during a lane change maneuver in three type of condition which is low speed maneuver, medium speed maneuver and high speed maneuver. Four-Wheel Steering – Rear Wheels Control. For parking and low-speed maneuvers, the rear Wheel steer in the opposite direction of the front wheels, allowing much sharper turns.

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LIST OF SYMBOL

- $D\phi$ = Roll axis damping, Nm/rad
 $K\phi$ = Roll axis stiffness, Nm/rad
 ϕ = Vehicle roll angle, rad
 C_f = Front cornering stiffness, N/rad
 C_r = Rear cornering stiffness, N/rad
 F_{xij} = Tire longitudinal force, N
 F_{yij} = Lateral force, N
 G = Gravity acceleration, ms^{-2}
 h_s = Distance of the sprung mass c.g. from the roll axes, m
 I_{xx} = Moment of inertia about roll axis, kg m^2
 I_{xz} = Sprung mass product of inertia, kg m^2
 I_{zz} = Moment of inertia about yaw axis, kg m^2
 L_f = Distance from c.g. to front axle, m
 L_r = Distance from c.g. to rear axle, m
 m = Vehicle total mass, kg
 m_s = Vehicle sprung mass, kg
 T_f = Front track width, m
 T_r = Rear track width, m
 u = Longitudinal velocity, ms^{-1}
 v = Lateral velocity, ms^{-1}
 X_{ij} = Longitudinal tire force, N
 Y_{ij} = Lateral tire force, N
 α_f = Front wheel slip angle, rad
 α_r = Rear wheel slip angle, rad
 β = Vehicle sideslip angle, rad
 $\gamma, \dot{\psi}$ = Yaw rate, rad/sec
 δ_f = Front wheel steering angle, rad
 δ_r = Rear wheel steering angle, rad

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CHAPTER 1

INTRODUCTION

Steering is the term applied to the collection of components, linkages, which will allow for a vessel or vehicle to follow the desired course. An exception is the case of rail transport by which rail tracks combined together with railroad switches provide the steering function.

The most conventional steering arrangement is to turn the front wheels using a hand-operated steering wheel, which is positioned in front of the driver, through the steering column, which may contain universal joints to allow it to deviate somewhat from a straight line. Other arrangements are sometimes found on different types of vehicles, for example, a tiller or rear-wheel steering. Tracked vehicles such as tanks usually employ differential steering that is, the tracks are made to move at different speeds or even in opposite directions to bring about a change of course.

In this steering systems capable of different modes of steering, some kind of means must be provided for maintaining the wheels synchronized when shifting from one mode of steering to another. Therefore such means have been relatively expensive, complex, easily put out of adjustment or some combination of the above. Therefore, one of the principal objects of my invention is to provide a wheel synchronization system that is inexpensive, simple and rugged.

1.1PROJECT OVERVIEW:

1.1.1 EXISTING SYSTEM:

In our existing system, we use 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 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.

1.1.2 DISADVANTAGES:

- It is very expensive.
- It is complex in design.
- It will be easily put out of adjustment.

1.1.3 PROPOSED SYSTEM:

In our proposed system, we introduce steering systems capable of conventional two-wheel steering, oblique or lateral steering and conventional four-wheel steering. By oblique or lateral steering, I mean that in a vehicle having two pairs of dirigible wheels all of them pivot simultaneously in the same direction with the result that the vehicle moves sideways without changing its heading.

By four-wheel steering, I mean that in a vehicle having two pairs of dirigible wheels one of the pairs of dirigible wheels pivots in one direction while the other pair of dirigible wheels pivots simultaneously in the opposite direction with the result that both pairs of wheels follow the same arc during turning.

1.1.4 ADVANTAGES:

- Easy maintenance.
- Mode change is easy.
- Implementation is easy.

1.2 WORKING PRINCIPLE:



Figure 1: Gear mesh:

Our project consists of a steering setup, spur gears, bevel gears and lock nut. The three modes are

1. Front wheel steer
2. Both front and rear wheel steer in same direction
3. Both wheels in opposite direction

When the lock nut is removed, the steering operation is carried out in normal condition. That is only front wheels steer. 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 are 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 is engaged. Due to bevel gear arrangement, the rear wheel steers in opposite direction to the front wheel. This results in third mode steering

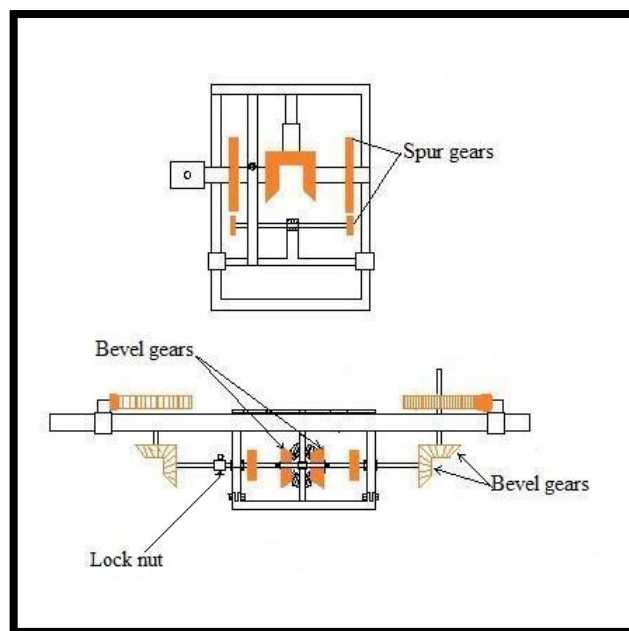


Figure 2: WORKING PRINCIPLE

1.2.1FRONT WHEEL STEERING:

In a front wheel, steering, only front wheels steer, and in a rear wheel, steering only rear wheels will steer to get turning. In a four-wheel steering system at low speeds, the front wheels and rear wheels are out of phase for low turning radius. However at high speeds,

The front and rear wheels should be in phase to increase the stability of a vehicle. So the lock nut is removed, the steering operation is carried out in normal condition. That is only front wheels steer.



Figure 3:1ST MODE OF OPERATION

1.2.2 BOTH FRONT AND REAR WHEEL STEER IN A SAME DIRECTION:

In Both front and rear wheel steer operation when the lock nut is inserted, the other two modes can be used. When the gear arrangement is pushed to one position, the bevel gears get engaged and the steering of rear wheel is ensured and is in same direction as that of the front wheels.



Figure 4: 2nd Mode of Steering

1.2.3 BOTH WHEELS IN OPPOSITE DIRECTION:

When the gear arrangement is moved to other side, the bevel gear disengages and the bevel gear gets engaged. Due to spur gear arrangement, the rear wheel steers in opposite direction to the front wheel. This results in third mode steering. Three steering modes can be changed as needed which assists in parking at heavy traffic conditions, when negotiating areas where short turning radius is needed and in off road Driving.



Figure 5: 3RD MODE OF OPERATION

1.3 PROBLEM DEFINITION:

Nowadays all vehicles use 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 based on how to prove that the 4WS is better than 2WS in terms of turning radius.

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.

CHAPTER 2

LITERATURE REVIEW

Lohith [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.

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.

Sathyabalan[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[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 a 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 288V I6AH 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[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[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 [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 1090m ild 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[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.

HONDA 4WS SYSTEM [11] This system is dependent on the steer angle so that the movement of the rear wheels is controlled by the angular movement of the front wheels. For steering of the front wheels up to about 130 degrees, the rear wheels are so arranged that they turn through a small angle in the same direction as the front wheels. Beyond this angle, the rear wheels gradually straighten up and then turn through a comparatively large angle in the opposite direction .

An Epicyclic gear mechanism incorporated in the rear steering gearbox controls the rear wheels angles. A fixed annulus is meshed with a large planet gear, which is driven by an eccentric on the input shaft. A short shaft in integral with the planet and is offset from the centre of the planet. This shaft transmits a drive through a slider and guide to a stroke rod, connected to the rear wheel track rods .

Slight movement of the input shaft rotates the planet which in turn moves the offset output shaft slightly in the same direction as the input. As the input shaft moves the offset shaft towards the TDC position , the stroke rod rotates back to the central position so that the rear wheels are set in a straight ahead position.

As the input shaft and planet are rotated towards the full-lock position, the stroke rod attains maximum displacement and consequently a corresponding movement of the rear wheels takes place. The rear gearbox is maintenance free and is greased for its entire life. The centre shaft couplings have splines to both steering gearboxes. A master spline at each connected point ensures correct assembly of the units.

MAZDA 4WS SYSTEM [12] The rear wheels in this system are steered by a hydraulically operated power unit, which is electronically controlled in accordance with the steering wheel angle and vehicle speed. The Mazda 4WS layout is more complicated than the Honda arrangement and hence incorporates suitable fail-safe for trouble free operation. The fail-safe device includes a centering lock spring and special safety solenoid. If hydraulic or electronic failure takes place, these devices set the rear wheels to the straight-ahead position.

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.

. A fixed annulus is meshed with a large planet gear, which is driven by an eccentric on the input shaft. A short shaft in integral with the planet and is offset from the centre of the

planet. This shaft transmits a drive through a slider and guide to a stroke rod, connected to the rear wheel track rods .

Two electronic sensors, installed at transmission output and speedometer drive, measure the vehicle speed. The signals are passed to the built-in memory of an electronic control unit (ECU), which commands the hydraulic system for setting the direction and angle for the rear wheels. For speeds less than 35 kmph, the rear wheels are steered in the opposite direction to that of the front wheels. As 35 kmph is approached, the rear wheels are turned to the straight-ahead position. Above this speed the rear wheels are steered in the same direction as the front wheels with an angle limited to 5 degrees.

The functions of these components in steering the rear wheels are as follows:

1. Sensors to measure vehicle speed.
2. Steering phase control unit conveys to the hydraulic control valve the required stroke direction of movement. (Hi) Electric stepper motor alters the yoke angle and bevel gear phasing in accordance with the signals received from the ECU.
3. Rear steering shaft provides the position of the front wheels to the bevel gear in the steering phase control unit.
4. Control valve controls the hydraulic pressure supplied to the ram cylinder.

Hydraulic ram cylinder steers the rear wheels depending upon the requirements.

The most effective type of steering, this type has all the four wheels of the vehicle used for steering purpose. 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. 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.

Compared with a conventional two wheel steering system, the advantages offered by a four-wheel steering system include:

1. Superior cornering stability.
2. Improved steering responsiveness and precision.
3. High speed straight-line stability.
4. Notable improvement in rapid lane changing maneuvers.
5. Smaller turning radius and tight space maneuverability at low speed.
6. Relative wheel angles and their control.

Usually in vehicles during turning, the tires are subject to the forces of grip, momentum, and steering input when making a movement other than straight-ahead driving. These forces compete with each other during steering manoeuvres. With a front-steered vehicle, the rear end is always trying to catch up to the directional changes of the front wheels. This causes the vehicle to sway. When turning, the driver is putting into motion a complex series of forces. Each of these must be balanced against the others. The tires are subjected to road grip and slip angle. Grip holds the car's wheels to the road, and momentum moves the car straight ahead. Steering input causes the front wheels to turn. The car momentarily resists the turning motion, causing a tire slip angle to form. Once the vehicle begins to respond to the steering input, cornering forces are generated. The vehicle sways as the rear wheels attempt to keep up with the cornering forces already generated by the front tires. This is referred to as rear-end lag because there is a time delay between steering input and vehicle reaction. When the front wheels are turned back to a straight-ahead position, the vehicle must again try to adjust by reversing the same forces developed by the turn. As the steering is turned, the vehicle body sways as the rear wheels again try to keep up with the cornering forces generated by the front wheels. 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.

2.1 PARALLEL PARKING:

Zero steer can significantly ease 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 itself between the two other cars parked on the service lane. This maneuver requires a three-way movement of the vehicle and consequently heavy steering inputs.

More over to successfully park the vehicle without incurring any damage at least 1.75 times the length of the car must be available for parking a two wheeled steer car. As can be seen clearly the car requires just about the same length as itself to park in the spot.

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.

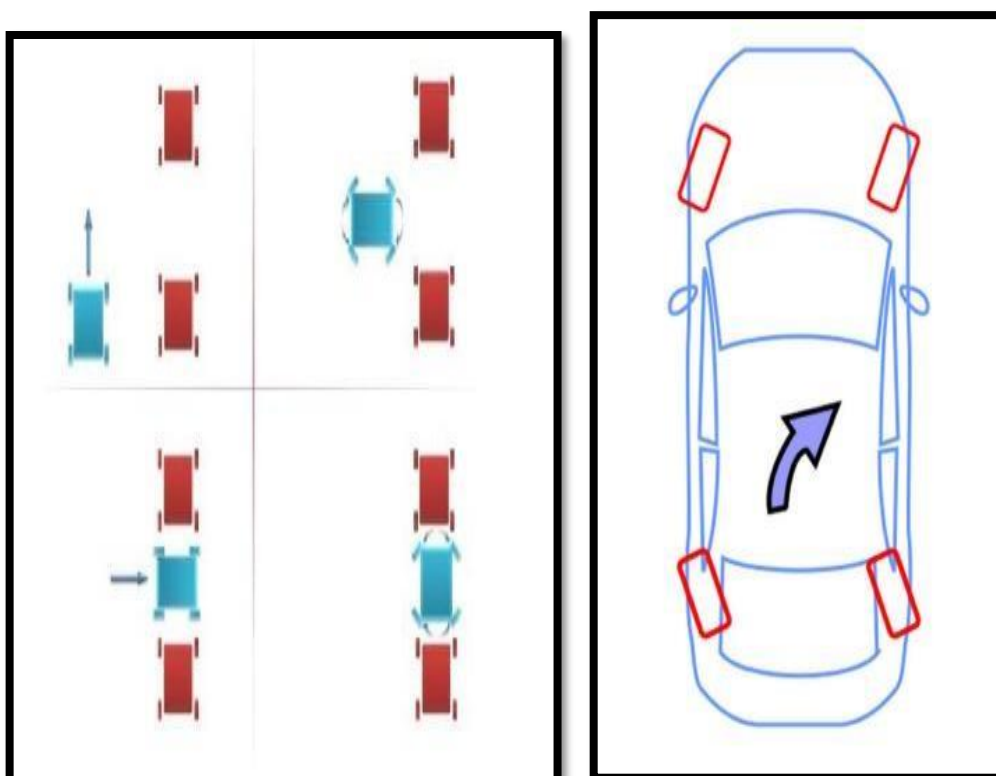


Figure 6: Parallel parking maneuvers

2.2.High speed lane changing:

Another driving manoeuvre that frequently becomes cumbersome and even dangerous is changing lanes at high speed. Although this is less steering, sensitive this does require a lot of concentration from the driver since he has to judge the space and vehicles behind them.

The vehicle with arrows is the model under study. As can be seen from the figure the vehicle can turn with hardly any space requirement with a single steering action and also resume without any corrective inputs. Thus, it also acts as a driver aid helping relatively inexperienced drivers make quick lane changes even at high speeds.

The company Honda Prelude manufactured the first four-wheel steering car and it defines four wheel steering, as the effect of the 4WS mechanism acting in this way was non-linear steering. That is, the effective steering ratio varied from a low ratio at small steering angles, to high ratio at large angle

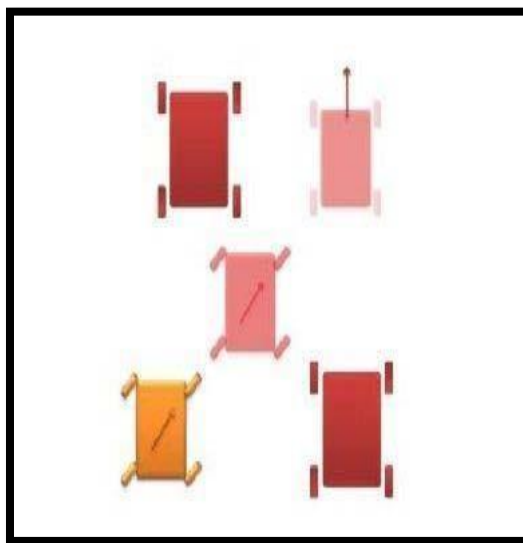


Figure 7:High-speed lane change manoeuvres

This means more steering angle input is required to perform a gradual turn, making the car less twitchy and more relaxed to drive at high speed, without requiring constant corrections; while less steering angle is required to perform a tight-radius turn, giving the car a go-kart like feel during tight manoeuvres.

The observed effect while driving might be best imagined as a variable effective wheelbase, from a long wheelbase at small steering angles, to very short wheelbase at large angles. It conducted experiment and calculated for the turning radius and suggested low speed turning performance is improved by steering the rear wheels out of phase with the front wheels to reduce the turn radius, thus improving maneuverability.

Normally the rear wheel steer angles are a fraction of that at the point (typically limited to about 5 degrees of steer) and may only be applied at low speeds. At 50 percent rear steer angle, a one-third reduction in turn radius is achieved. At 100 percent rear steer angle, a 50 percent reduction in turn radius occurs. The primary advantage of 4WS is derived from the better control of transient behavior in cornering. In general, 4WS systems yield a quicker response with better damping of the yaw oscillation that occurs with initiation of a turn.

2.3. APPLICATION IN HEAVY VEHICLES

The earliest application for mechanical four-wheel steering was to reduce turning circles for heavy commercial vehicles and pickup trucks. It stays true even today, with commercial vehicles from GM sporting this feature.

It is comparatively easier to implement rear steer mode in trailers than in rear axles of buses, as the rear axle is a driven member and has two additional wheels, which will raise the specification as well the cost of the steering motors. A simple rack-and-pinion steering can be used upfront and an electronic steering system can be configured such that both wheels turn at appropriate angles to increase the effectiveness of the steering system. Moreover, zero steer mode can also be implemented in buses, to ease the problem of parking in depots. The steering mechanism might have to be changed, however, in this case. However, the two steering modes described in this project can be successfully implemented in heavy vehicles, as it described in a similar four-wheel steered trailer-bus.



Figure 8: Trailer Bus with Four-Wheel Steering

CHAPTER 3

MATERIALS AND COMPONENTS

The four wheels steering with three mode operation consists of the following components to full fill the requirements of complete operation of the machine.

- Rack and pinion
- Bevel gear
- Spur gear
- Steering
- Wheel
- Hinge joint

The material selected must possess the necessary properties for the proposed application. The various requirements to be satisfied can be weight, surface finish, rigidity, ability to withstand environmental attack from chemicals, service life, reliability etc.

4.1 GEAR:

Gear or cogwheel is a rotating machine part having cut teeth, or cogs, which mesh with another toothed part to transmit torque, in most cases with teeth on the one gear being of identical shape, and often also with that shape on the other gear. Two or more gears working in a sequence (train) are called a gear train or, in many cases, a transmission; such gear arrangements can produce a mechanical advantage through a gear ratio and thus may be considered a simple machine. Geared devices can change the speed, torque, and direction of a power source. The most common situation is for a gear to mesh with another gear; however, a gear can also mesh with a non-rotating toothed part, called a rack, thereby producing translation instead of rotation.

The gears in a transmission are analogous to the wheels in a crossed belt pulley system. An advantage of gears is that the teeth of a gear prevent slippage. When two gears mesh, and one gear is bigger than the other is (even though the size of the teeth must match), a mechanical advantage is produced, with the rotational speeds and the torques of the two gears differing in an inverse relationship.

In transmissions with multiple gear ratios such as bicycles, motorcycles, and cars, the term gear, as in first gear, refers to a gear ratio rather than an actual physical gear. The term describes similar devices, even when the gear ratio is continuous rather than discrete, or when the device does not actually contain gears, as in continuously.

4.2 COMPARISON WITH DRIVE MECHANISMS:

The definite velocity ratio that teeth give gears provides an advantage over other drives (such as traction drives and V-belts) in precision machines such as watches that depend upon an exact velocity ratio. In cases where driver and follower are proximal, gears also have an advantage over other drives in the reduced number of parts required; the downside is that gears are more expensive to manufacture and their lubrication requirements may impose a higher operating cost.

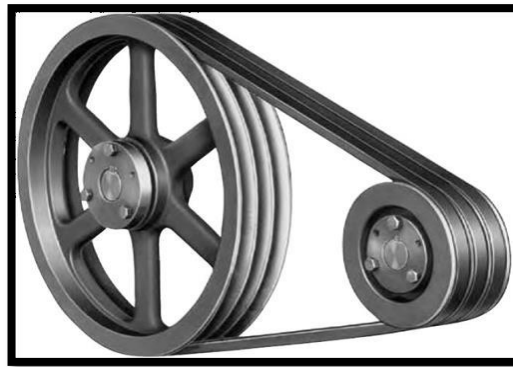


Figure 9:V-BELT DRIVE

4.3 TYPES

4.3.1 EXTERNAL VS INTERNAL GEARS:

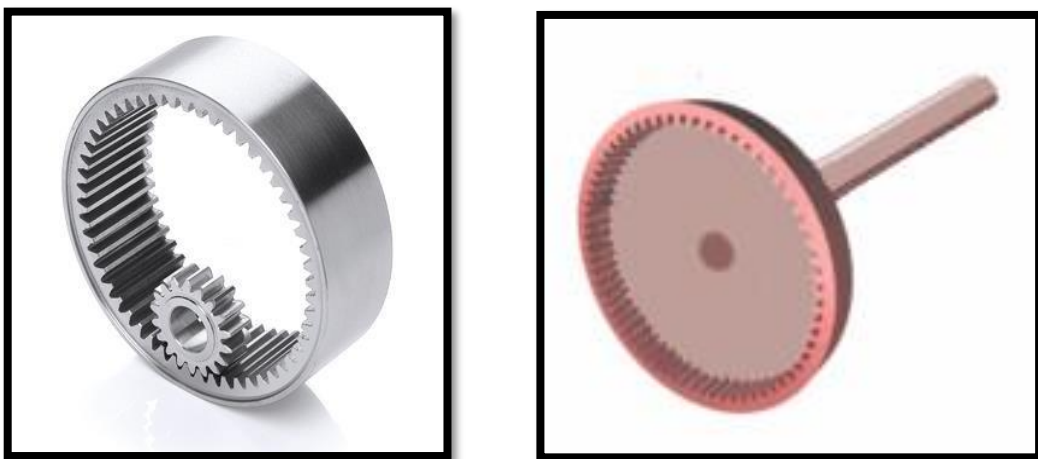


Figure 10External vs Internal gear

An external gear is one with the teeth formed on the outer surface of a cylinder or cone. Conversely, an internal gear is one with the teeth formed on the inner surface of a cylinder or cone. For bevel gears, an internal gear is one with the pitch angle exceeding 90 degrees. Internal gears do not cause output shaft direction reversal.

4.3.2 SPUR GEAR:

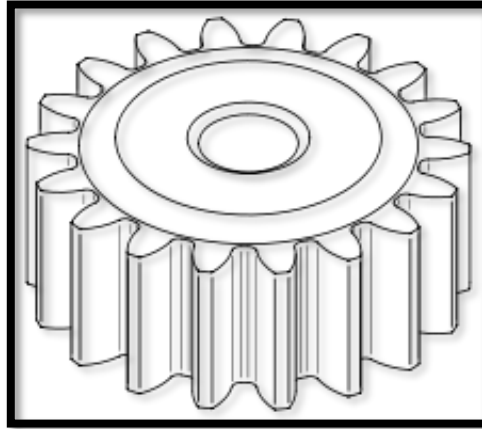


Figure 11:Spur gear

Spur gears or straight-cut gears are the simplest type of gear. They consist of a cylinder or disk with the teeth projecting radially, and although they are not straight-sided in form (they are usually of special form to achieve constant drive ratio, mainly involute), the edge of each tooth is straight and aligned parallel to the axis of rotation. These gears can be meshed together correctly only if they are fitted to parallel shafts.

4.3.3 HELICAL GEAR:

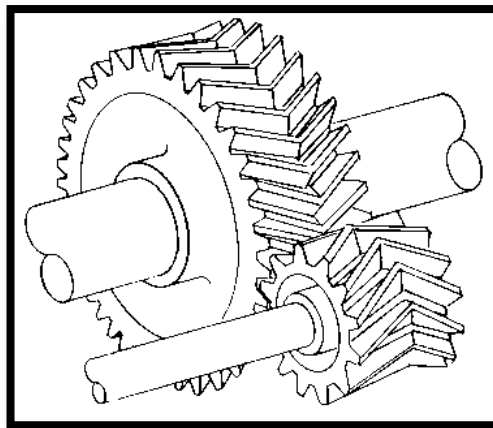


Figure 12:Helical gear

Helical or "dry fixed" gears offer a refinement over spur gears. The leading edges of the teeth are not parallel to the axis of rotation, but are set at an angle. Since the gear is curved, this angling causes the tooth shape to be a segment of a helix. Helical gears can be meshed in parallel or crossed orientations. The former refers to when the shafts are parallel to each other; this is the most common orientation. In the latter, the shafts are non-parallel, and in this configuration the gears are sometimes known as "skew gears".

The angled teeth engage more gradually than do spur gear teeth, causing them to run more smoothly and quietly. With parallel helical gears, each pair of teeth first make contact at a single point at one side of the gear wheel; a moving curve of contact then grows gradually across the tooth face to a maximum then recedes until the teeth break contact at a single point on the opposite side. In skew gears, teeth suddenly meet at a line contact across their entire width causing stress and noise. Spur gears make a characteristic whine at high speeds. Whereas spur gears are used for low speed applications and those situations where noise control is not a problem, the use of helical gears is indicated when the application involves high speeds, large power transmission, or where noise abatement is important. The speed is considered high when the pitch line velocity exceeds 25 m/s.

A disadvantage of helical gears is a resultant thrust along the axis of the gear, which needs to be accommodated by appropriate thrust bearings, and a greater degree of sliding friction between the meshing teeth, often addressed with additives in the lubricant.

4.3.4 SKEW GEARS:

For a 'crossed' or 'skew' configuration, the gears must have the same pressure angle and normal pitch; however, the helix angle and handedness can be different. The relationship between the two shafts is actually defined by the helix angle(s) of the two shafts and the handedness.

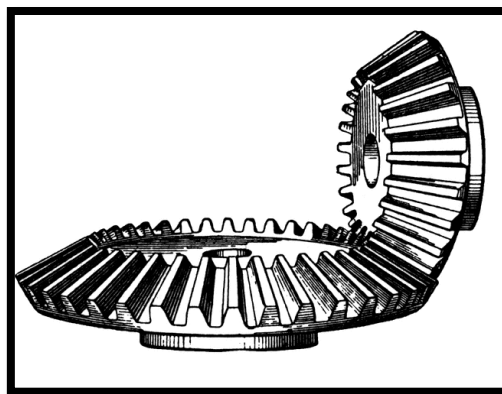


Figure 13:Skew gear

$$E = \beta_1 + \beta_2 \quad \text{For gears of the same handedness}$$

$$E = \beta_1 - \beta_2 \quad \text{For gears of opposite handedness}$$

Where β is the helix angle for the gear. The crossed configuration is less mechanically sound because there is only a point contact between the gears, whereas in the parallel

configuration there is a line contact. Quite commonly, helical gears are used with the helix angle of one having the negative of the helix angle of the other; such a pair might also be referred to as having a right-handed helix and a left-handed helix of equal angles.

The two equal but opposite angles add to zero: the angle between shafts is zero that is, the shafts are parallel. Where the sum or the difference (as described in the equations above) is not zero the shafts are crossed. For shafts crossed at right angles, the helix angles are of the same hand because they must add to 90 degrees.

4.3.5 DOUBLE HELICAL:

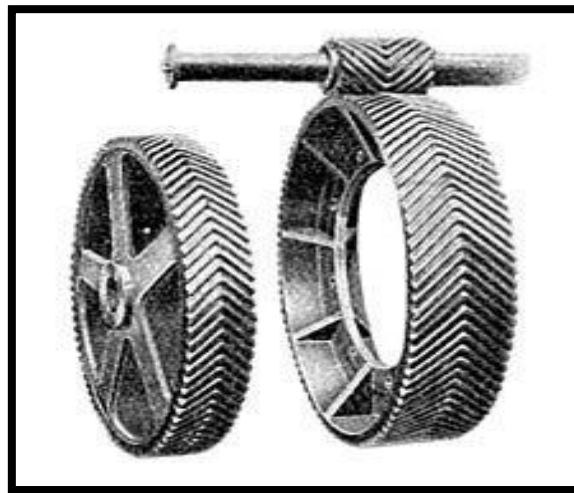


Figure 14: Double helical gear

Double helical gears, or herringbone gears, overcome the problem of axial thrust presented by "single" helical gears, by having two sets of teeth that are set in a V shape. A double helical gear can be thought of as two mirrored helical gears joined together. This arrangement cancels out the net axial thrust, since each half of the gear thrusts in the opposite direction resulting in a net axial force of zero. This arrangement can remove the need for thrust bearings. However, double helical gears are more difficult to manufacture due to their more complicated shape.

For both possible rotational directions, there exist two possible arrangements for the oppositely-oriented helical gears or gear faces. One arrangement is stable, and the other is unstable. In a stable orientation, the helical gear faces are oriented so that each axial force is directed toward the center of the gear. In an unstable orientation, both axial forces are directed away from the center of the gear.

In both arrangements, the total (or net) axial force on each gear is zero when the gears are aligned correctly. If the gears become misaligned in the axial direction, the unstable arrangement generates a net force that may lead to disassembly of the gear train,

while the stable arrangement generates a net corrective force.

4.3.6 BEVEL GEAR:



Figure 15: BEVEL GEAR

A bevel gear is shaped like a right circular cone with most of its tip cut off. When two bevel gears mesh, their imaginary vertices must occupy the same point. Their shaft axes also intersect at this point, forming an arbitrary non-straight angle between the shafts. The angle between the shafts can be anything except zero or 180 degrees. Bevel gears with equal numbers of teeth and shaft axes at 90 degrees are called miter gears.

4.3.7 SPIRAL BEVEL GEAR:



Figure 16: Spiral bevel gears

Spiral bevel gears can be manufactured as Gleason types (circular arc with non-constant tooth depth), Oerlikon and Curvex types (circular arc with constant tooth depth), Klingelnberg Cyclo-Paloid (Epicycloide with constant tooth depth) or Klingelnberg Palloid.

Spiral bevel gears have the same advantages and disadvantages relative to their straight-cut cousins as helical gears do to spur gears. Straight bevel gears are generally used only at speeds below 5 m/s (1000 Ft. /min), or, for small gears, 1000 r.p.m.

Mean spiral angle is the specific designation for the spiral angle at the mean cone distance in a bevel gear. Outer spiral angle is the spiral angle of a bevel gear at the outer cone distance. Inner spiral angle is the spiral angle of a bevel gear at the inner cone distance.

4.3.8 HYPOID GEAR:

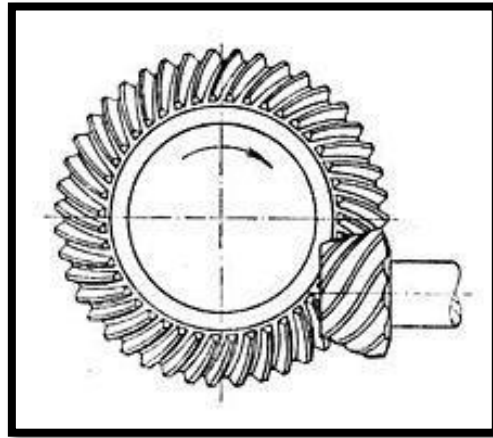


Figure 17: Hypoid gear

Hypoid gears resemble spiral bevel gears except the shaft axes do not intersect. The pitch surfaces appear conical but, to compensate for the offset shaft, are in fact hyperboloids of revolution. Hypoid gears are usually designed to operate with shafts at 90 degrees.

Depending on which side the shaft is offset to, relative to the angling of the teeth, contact between hypoid gear teeth may be even smoother and more gradual than with spiral bevel gear teeth, but also have a sliding action along the meshing teeth as it rotates and therefore usually require some of the most viscous types of gear oil to avoid it being extruded from the mating tooth faces, the oil is normally designated HP (for hypoid) followed by a number denoting the viscosity. Also, the pinion can be designed with fewer teeth than a spiral bevel pinion, with the result that gear ratios of 60:1 and higher are feasible using a single set of hypoid gears. This style of gear is most common in motor vehicle drive trains, in concert with a differential.

Whereas a regular (nonhypoid) ring-and-pinion gear set is suitable for many applications, it is not ideal for vehicle drive trains because it generates more noise and vibration than a hypoid does. Bringing hypoid gears to market for mass-production applications was an engineering improvement

4.3.9 CROWN GEAR:

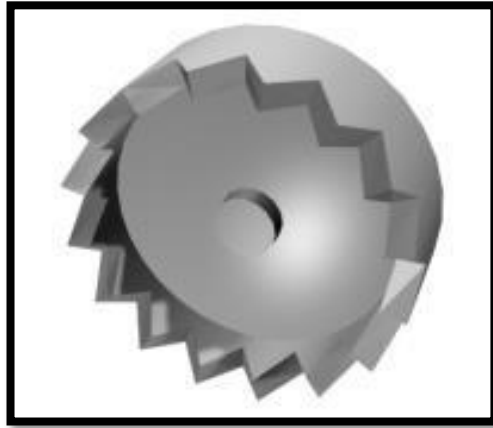


Figure 18: Crown gear

Crown gears or contrite gears are a particular form of bevel gear whose teeth project at right angles to the plane of the wheel; in their orientation the teeth resemble the points on a crown. A crown gear can only mesh accurately with another bevel gear, although crown gears are sometimes seen meshing with spur gears. A crown gear is also sometimes meshed with an escapement such as found in mechanical clocks.

4.3.10 WORM GEAR:

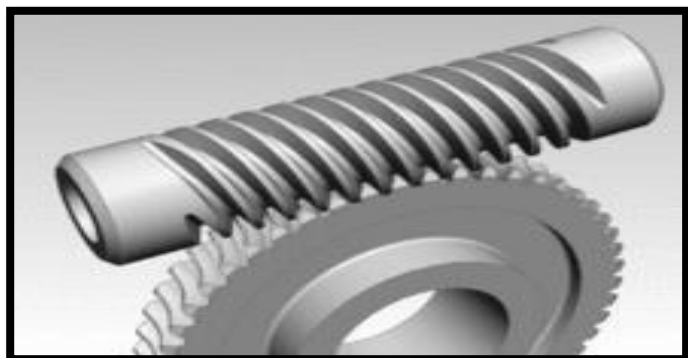
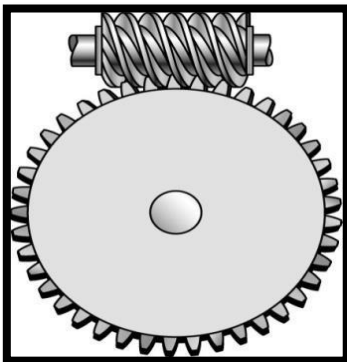


Figure 19: Worm gear

Worms resemble screws. A worm is meshed with a worm wheel, which looks similar to a spur gear. Worm-and-gear sets are a simple and compact way to achieve a high torque, low speed gear ratio. For example, helical gears are normally limited to gear ratios of less than 10:1 while worm-and-gear sets vary from 10:1 to 500:1. A disadvantage is the potential for considerable sliding action, leading to low efficiency.

A worm gear is a species of helical gear, but its helix angle is usually somewhat large (close to 90 degrees) and its body is usually fairly long in the axial direction. These attributes give it screw like qualities. The distinction between a worm and a helical gear is

that least one tooth persists for a full rotation around the helix. If this occurs, it is a 'worm'; if not, it is a 'helical gear'. A worm may have as few as one tooth. If that tooth persists for several turns around the helix, the worm appears, superficially, to have more than one tooth, but what one in fact sees is the same tooth reappearing at intervals along the length of the worm. The usual screw nomenclature applies: a one-toothed worm is called single thread or single start; a worm with more than one tooth is called multiple thread or multiple start. The helix angle of a worm is not usually specified. Instead, the lead angle, which is equal to 90 degrees minus the helix angle, is given. In a worm-and-gear set, the worm can always drive the gear. However, if the gear attempts to drive the worm, it may or may not succeed. Particularly if the lead angle is small, the gear's teeth may simply lock against the worm's teeth, because the force component circumferential to the worm is not sufficient to overcome friction.

Worm-and-gear sets that do lock are called self-locking, which can be used to advantage, as for instance when it is desired to set the position of a mechanism by turning the worm and then have the mechanism hold that position. An example is the machine head found on some types of stringed instruments.

If the gear in a worm-and-gear set is an ordinary helical gear only a single point of contact is achieved. If medium to high power transmission is desired, the tooth shape of the gear is modified to achieve more intimate contact by making both gears partially envelop each other. This is done by making both concave and joining them at a saddle point; this is called a cone-drive. Or "Double enveloping". Worm gears can be right or left-handed, following the long-established practice for screw threads.

CHAPTER 4

STEERING MECHANISM AND FABRICATION

BRIEF DESCRIPTION OF STEERING PARTS

6.1.1 Steering Wheel:

It is made up of steel ring welded together on a hub with the help of two, three or four spokes. After welding ring with the spokes is ebonite moulded on it.

6.1.2 Steering Column:

This is a hollow steel pipe in which steering shaft is housed. One end of the pipe is fixed on the steering box, while the other end is usually held with the help of bracket under the instrument panel.

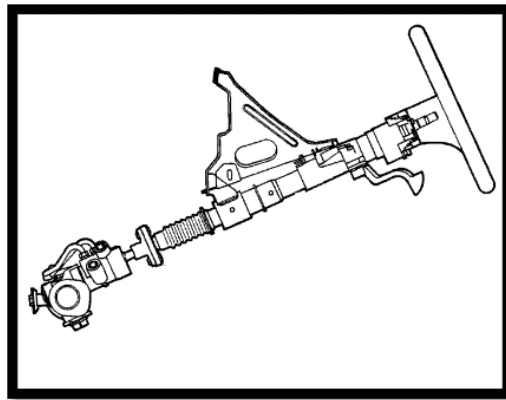


Figure 20: STEERING COLUMN

6.1.3 Steering Shaft

It is made up of good quality steel. One end is fixed in the steering wheel with the help of splines or key and kept tight by nut. The other end with worm is secured firmly in the steering box with the help of bearing placed both on top and bottom. Sometimes, instead of one shaft, two pieces of shaft are also used.

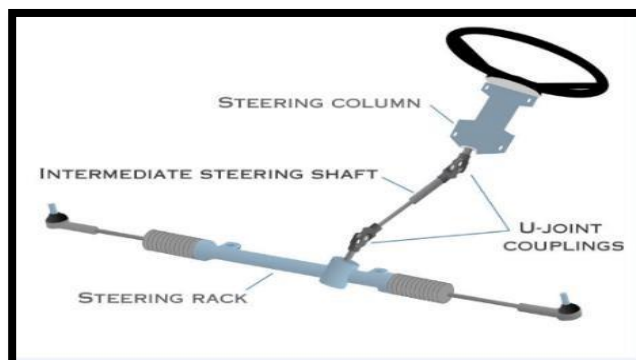


Figure 21: STEERING SHAFT

6.1.4 Steering Gear Box

Its function is to convert rotary motion of wheel in to-and-fro motion of drop arm so that the drag link tied up with drop arm can be pushed or pulled resulting into moving stub axle to right or left as desired by the driver.

6.1.5 Drop arm

It is forged out of good quality steel. Its one side is provided with splines which match the spline sector shaft and held on sector shaft by nut. The other end has a tapered hole in which ball end is held tight with the help of nut.

6.1 STEERING PRINCIPLES AND COMPONENTS

6.2.1 Ackermann Steering Mechanism

With perfect Ackermann, at any angle of steering, the centre point of all of the circles traced by all wheels will lie at a common point. But this may be difficult to arrange in practice with simple linkages. 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 manoeuvres.

6.2.2 Steering Ratio

The steering ratio is the number of degrees that the steering wheel must be turned to pivot the front wheels 1 degree. E.g.: steering ratio 18:1 implies that the front wheels will turn by 1 degree when the steering wheel turns 18 degree. The steering ratios generally used with present day steering gears vary from about 12: 1 for cars to about 35: 1 for heavy vehicles. An average overall ratio usually gives about one and half complete turns of the steering wheel each side of mid position to apply a full lock of 45 degrees each way on the wheels.

6.2.3 Turning Circle

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 an approximate value can be obtained using the formula:

$$\text{Turning circle radius} = \left(\frac{\text{turn}}{2} \right) + \left(\text{wheel} \frac{\text{base}}{\sin(\text{average steer angle})} \right)$$

6.2.4 Steering Geometry

When a car is moving along a curve, all its wheels should roll truly without any lateral slip. This can be achieved if the axis of all four wheels intersects at one point. This point will be the centre about which the vehicle will be turning at that instant. Figure shows the steering geometry of the four wheels of a vehicle. The rear wheels rotate along two circles. The centres of both these circles are at O. The front wheels 1 and 2 have different axes. They rotate along two other circles with the same centre point. For correct functioning of any steering system, the centre of the wheels of the rear axles and of wheels 1, 2 should coincide.

6.2.5 Wheel Alignment

Wheel alignment refers to the positioning of the wheels and steering mechanism that gives the vehicle directional stability, promotes ease of steering and reduces tyre wear to minimum.

A wheel is said to have directional stability or control if it can:

- Run straight down a road
- Enter and leave a turn easily
- Resist road shocks

Factors pertaining to steering geometry are:

6.2.6 King-pin inclination or steering axle inclination:

The angle between the vertical line and centre of the king pin or steering axle, when viewed from the front of the vehicle is known as king pin inclination or steering axle inclination.

- It helps the car to have steering stability
- It makes the operation of the steering quite easy particularly when the vehicle is stationary.
- It helps in reducing the wear on tyre

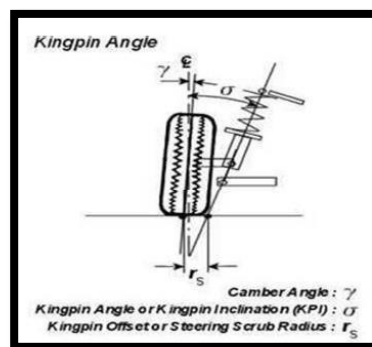


Figure 22: kingpin angle

6.2.7 Included angle:

The combined camber and king pin inclination is called included angle. It determines the point of intersection of the wheel and king pin centre lines. This in turn determines whether the wheel will tends to toe-in or toe-out

- If the point of intersection above the ground, the wheel tends to toe-in
- If it is below the ground, the wheel tends to toe-out
- If it is at ground, the wheel keeps its straight position without any tendency to toe-in or toe-out. In this position the steering is called centre point steering.

6.2.8 Caster:

In addition to being tilted inward toward the centre of the vehicle, the king pin axis may also be tilted forward or backward from the vertical line. This tilt is known as caster. Thus the angle between the vertical line and the king pin centre line in the plane of the wheel (when viewed from the side) is called caster angle.

Positive caster: If the king-pin centre line meets the ground at point ahead of the vertical centre line.

Negative caster: If the king-pin centre line meets the ground at point behind the vertical centre line. The caster angle in modern vehicle range from 2° - 8° . About 3° of caster gives the good result. The purpose of the caster is to give a trailing effect to the front wheels. When the wheel trails the line of weight that moves in the same direction as the vehicle it is easy to steer a straight course. Positive caster in wheels results in a natural tendency in wheels to toe-in. The negative caster would have the opposite effect. The positive caster increases the effort required to steer and tries to keep the wheels straight ahead. Negative caster is provided in heavy duty trucks for making steering easier.

When the caster at the two wheels are not equal, the tendency to toe-in at the wheel with the larger caster will be more which will cause the vehicle to pull constantly towards the side of the wheel with lesser caster.

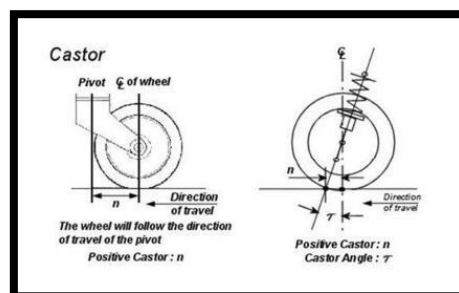


Figure 23: CASTOR

6.2.9 Camber:

The angle between the centre line of the tyre and the vertical line when viewed from the front of the vehicle is known as camber. Any amount of camber tends to cause uneven or more tyre wear on one side than on the other side. Camber should not exceed two degrees. Purpose of camber is to prevent the top of the wheels from tilting inwards too much because of excessive loads or play in kingpins and wheel bearing. When the vehicle is loaded and rolling along on the road, the load will just bring the wheels to a vertical position.

Positive camber: When upper part of wheel is outside.

Negative camber: When upper part of wheel is inside (towards the centre line of the car).

6.2.10 Toe-in:

The front wheels are usually turned in slightly in front so that the distance between the front ends is slightly less than the distance between the back ends, when viewed from the top. The difference between these distances is called toe in.

The actual amount of toe-in is usually ranges from 3 - 5 mm.

- 1) It ensures parallel running of the front wheels
- 2) It stabilizes steering
- 3) It prevents side slipping and excessive wear of the tyres
- 4) It also serves to offset the small deflections in the wheel support system which comes out then the vehicle is moving forward.

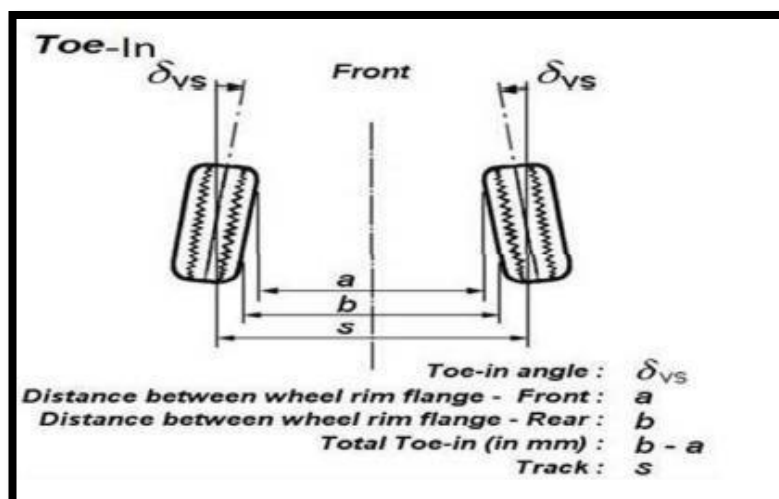


Figure 24:TOE-IN

6.2.11 Toe-out:

Toe-out is the difference in angles between the two front wheels and the car frame during turns. The toe-out is secured by providing the proper relationship between the steering knuckle arms, tie rods and pitman arm. The purpose of toe-out is to give correct turning alignment and to prevent excessive wear.

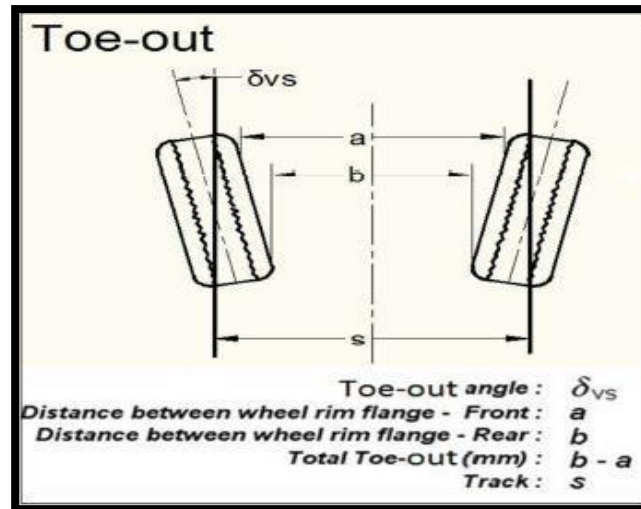


Figure 25:TOE-OUT

6.2 VEHICLE DYNAMICS AND STEERING

Vehicle dynamics have very importance for a balanced drive of vehicle. It can be say in three terms of steering, which are under-steer, over-steer, and neutral or counter steering.

6.3.1 Under-steer:

Under steer is so called because when the slip angle of front wheels is greater than slip angle of rear wheels. The diagram for the under steer is given below, from the diagram the explanation is made out clear very well.

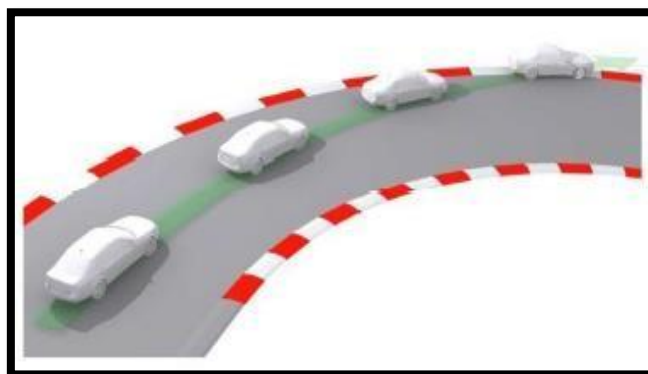


Figure 26:UNDER-STEER

6.3.2 Over-steer:

Over steer is defined when the slip angle of front wheels lesser than the slip angle of rear wheels.

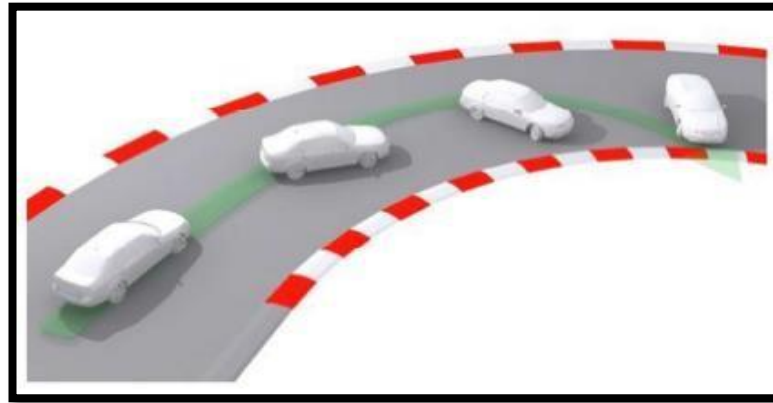


Figure 27:OVER-STEER

6.3.3 Neutral-steer or Counter-steering: Counter-steering can defined as when the slip angle of front wheels is equal to slip angle of rear wheels.

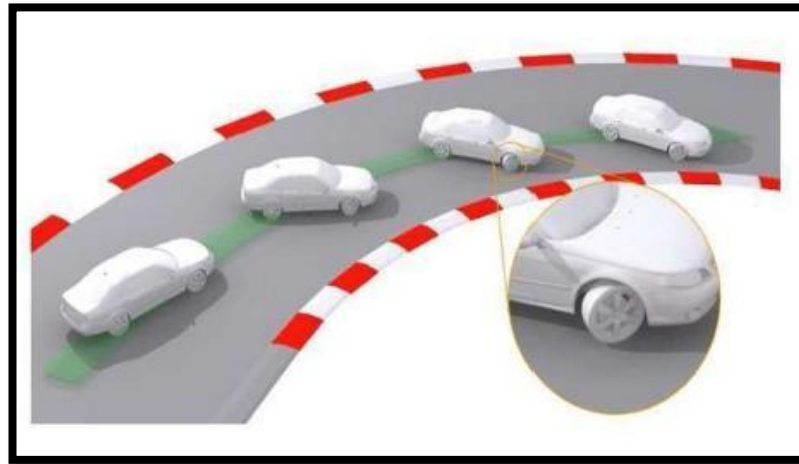


Figure 28:Neutral-Steer

7.1 PITMAN ARM

There really are only two basic categories of steering system today; those that have pitman arms with a steering 'box' and those that don't. Older cars and some current trucks use pitman arms. Newer cars and unibody light-duty trucks typically all use some derivative of rack and pinion steering.

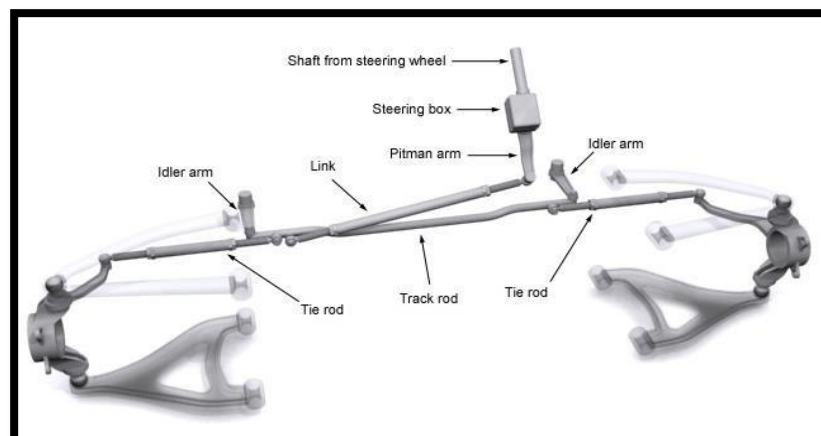


Figure 29: Pitman Arm Type

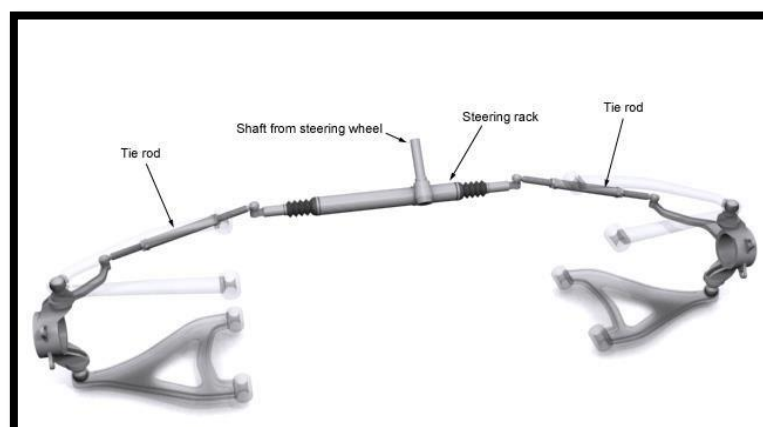
Pitman arm mechanisms have a steering 'box' where the shaft from the steering wheel comes in and a lever arm comes out - the pitman arm. This pitman arm is linked to the track rod or centre link, which is supported by idler arms. The tie rods connect to the track rod. There are a large number of variations of the actual mechanical linkage from direct-link where the pitman arm is connected directly to the track rod, to compound linkages where it is connected to one end of the steering system or the track rod via other rods. The example below shows a compound link.

Most of the steering box mechanisms that drive the pitman arm have a 'dead spot' in the centre of the steering where you can turn the steering wheel a slight amount before the front wheels start to turn. This slack can normally be adjusted with a screw mechanism but it can't ever be eliminated. The traditional advantage of these systems is that they give bigger mechanical advantage and thus work well on heavier vehicles. With the advent of power steering, that has become a moot point and the steering system design is now more to do with mechanical design, price and weight. The following are the four basic types of steering box used in pitman arm systems.

7.2 RACK AND PINION:

This is by far the most common type of steering you'll find in any car today due to its relative simplicity and low cost. Rack and pinion systems give a much better feel for the driver, and there isn't the slop or slack associated with steering box pitman arm type systems. The downside is that unlike those systems, rack and pinion designs have no adjustability in them, so once they wear beyond a certain mechanical tolerance, they need replacing completely. This is rare though.

In a rack and pinion system, the track rod is replaced with the steering rack which is a long, toothed bar with the tie rods attached to each end. On the end of the steering shaft there is a simple pinion gear that meshes with the rack. When you turn the steering wheel,



the pinion gear turns, and move the rack from left to right. Changing the size of the pinion gear alters the steering ratio. It really is that simple. The diagrams here show an example rack and pinion system (left) as well as a close-up cutaway of the steering rack itself (right).

Figure 30: Rack and Pinion Type.

7.2.1 Variable-Ratio Rack and Pinion Steering

This is a simple variation on the above design. All the components are the same, and it all works the same except that the spacing of the teeth on the rack varies depending on how close to the centre of the rack they are.

In the middle, the teeth are spaced close together to give slight steering for the first part of the turn - good for not over steering at speed. As the teeth get further away from the centre, they increase in spacing slightly so that the wheels turn more for the same turn of the steering wheel towards full lock.

7.3 RECIRCULATING BALL RACK AND SECTOR:

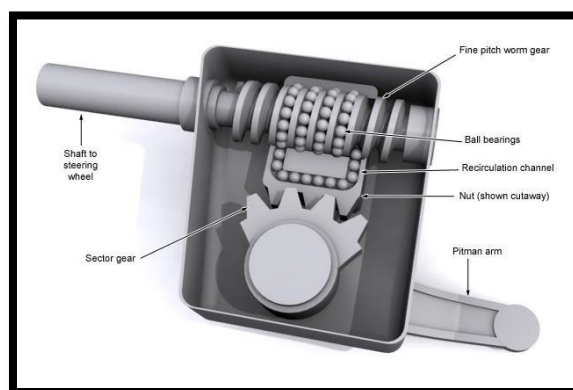


Figure 31: Rack and Pinion Type.

This is by far the most common type of steering box for pitman arm systems. In a recirculating ball steering box, the worm drive has many more turns on it with a finer pitch. A box or nut is clamped over the worm drive that contains dozens of ball bearings. These loop around the worm drive and then out into a recirculating channel within the nut where they are fed back into the worm drive again. As the steering wheel is turned, the worm drives turns and forces the ball bearings to press against the channel inside the nut. This forces the nut to move along the worm drive. The nut itself has a couple of gear teeth cast into the outside of it and these mesh with the teeth on a sector gear which is attached to the cross shaft just like in the worm and sector mechanism. This system has much less free play or slack in it than the other designs, hence why it's used the most. The example below shows a recirculating ball mechanism with the nut shown in cutaway so you can see the ball

bearings and the recirculation channel.

7.4 WORM AND SECTOR:

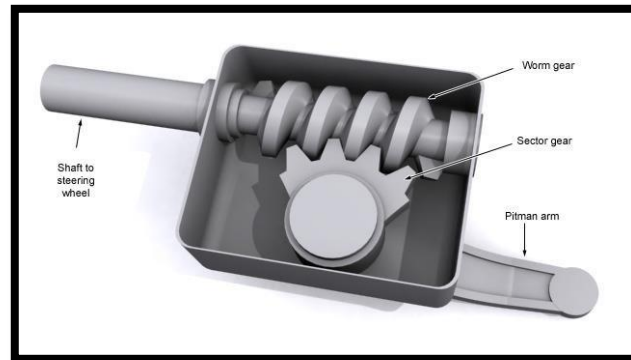


Figure 32: Worm and Sector.

In this type of steering box, the end of the shaft from the steering wheel has a worm gear attached to it. It meshes directly with a sector gear (so called because it's a section of a full gear wheel). When the steering wheel is turned, the shaft turns the worm gear, and the sector gear pivots around its axis as its teeth are moved along the worm gear. The sector gear is mounted on the cross shaft which passes through the steering box and out the bottom where it is splined, and the the pitman arm is attached to the splines. When the sector gear turns, it turns the cross shaft, which turns the pitman arm, giving the output motion that is fed into the mechanical linkage on the track rod.

7.5 WORM AND ROLLER:

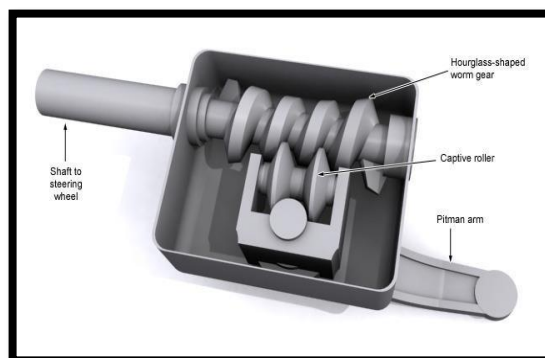


Figure 33:Worm and Roller.

The worm and roller steering box is similar in design to the worm and sector box. The difference here is that instead of having a sector gear that meshes with the worm gear, there is a roller instead. The roller is mounted on a roller bearing shaft and is held captive on the end of the cross shaft. As the worm gear turns, the roller is forced to move along it but because it is held captive on the cross shaft, it twists the cross shaft

7.6 CAM AND ROLLER:

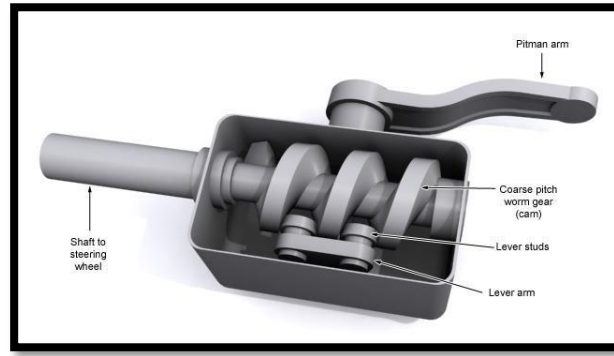


Figure 34: Cam and Roller

Cam and lever steering boxes are very similar to worm and sector steering boxes. As the worm gear is turned, the studs slide along the cam channels which forces the cross shaft to rotate, turning the pitman arm. One of the design features of this style is that it turns the cross shaft 90° to the normal so it exits through the side of the steering box instead of the bottom. This can result in a very compact design when necessary.

CHAPTER 5

DESIGN CALCULATION AND MODEL

8.1 CALCULATION FOR STEERING ANGLE:

Calculation for steering angles for the turning radius of 4.4m.

From the benchmark vehicle, we know that turning radius is 4.4 m.

We know that

$$R^2 = a_2^2 + R_1^2 \dots \dots \dots (1)$$

Where

R = Turning radius of the vehicle.

a_2 = Distance of CG from rear axle.

R_1 = Distance between instantaneous center and the axis of the vehicle.

To find a_2 :

$$W_f = (W * a_2) / L \dots \dots \dots (2)$$

Where

W_f = Load on front axle.

W = Total weight of car.

L = Wheelbase.

So from equation 2 and 1

$$a_2 = 1305 \text{ mm.}$$

$$R_1 = 4202 \text{ mm.}$$

TO FIND STEERING ANGLE:

From test we found that the inner angle of front tire is,

$$\delta_{if} = 25.6^\circ.$$

$$\tan \delta_{if} = C_1 / (R_1 - w_f / 2) \dots \dots \dots (3)$$

$$C_1 + C_2 = L \dots \dots \dots (4)$$

Where

C_1 = Distance of instantaneous centre from front axle axis.

C_2 = Distance of instantaneous centre from rear axle axis.

$$w_f = 452.80 \text{ mm.}$$

To find δ_{of} = outer angle of front tire.

$$\tan \delta_{of} = C_1 / (R_1 + w_f / 2) \dots \dots \dots (5)$$

$$\delta_{of} = 19.70^\circ$$

To find δ_{ir} = inner angle of rear tire.

$$\tan \delta_{ir} = C_2 / (R_1 - w_r / 2) \dots \dots \dots (6)$$

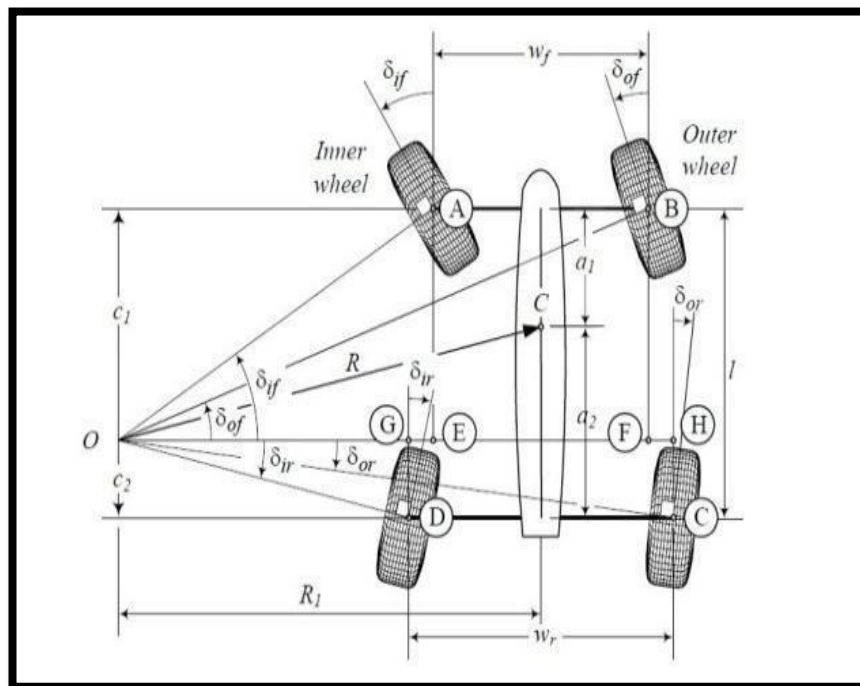
$$\delta_{ir} = 7.164^\circ$$

From
equation 3
and 4

$$C_1 = \frac{1}{1.72} \cdot \frac{1}{1.9}$$

To find δ_{if} = outer angle of rear tire.

$$\tan \delta_{or} = C_2 / (R_1 + w_r / 2) \dots \dots \dots (7)$$



$$\delta_{or} = 5.386^\circ$$

Figure 35:Steering angles position of instantaneous centre for turning radius 4.4m

Now considering the same steering angles for front and rear tires, we reduce in the turning radius of the vehicle but keeping the wheelbase and track width same as the benchmark vehicle.

8.2 CALCULATION OF TURNING RADIUS

TO FIND STEERING RADIUS, R

$$R^2 = a_2^2 + L^2 \cot^2 \delta \dots \dots \dots (8)$$

Where

δ = Total steering angle of the vehicle.

TO FIND δ

$$\cot \delta = (\cot \delta_i + \cot \delta_o) / 2 \dots \dots \dots (9)$$

Where δ_i = total inner angle of the vehicle.

δ_o = total outer angle of the vehicle.

$$\cot\delta = 1.032.$$

From equation 8

$$R = 2596 \text{ mm.}$$

calculation for C_1 and C_2 from equation 3 and 4 considering turning radius as 2596 mm.

$$C_1 = 780.82 \text{ mm.}$$

$$C_2 = 1394.17 \text{ mm.}$$

Considering C_1 and C_2 as Distance of instantaneous centre from front axle axis and rear axle.

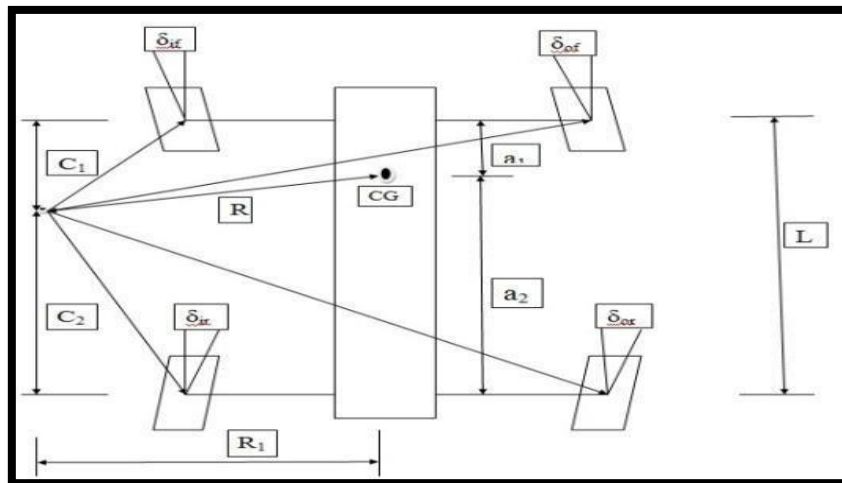
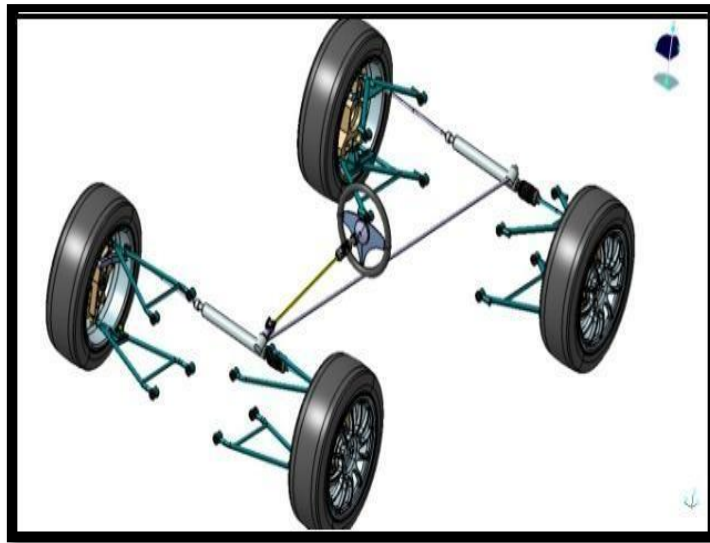


Figure 36:Steering angles and position of instantaneous centre for turning radius 2.59 m

From Figure 28 and 29 we can see that there is a change in instantaneous center as there is change in turning radius. The values of C_1 and C_2 changes gradually, in figure 3 the value of C_1 is greater and the value of C_2 is lesser but in Fig as the turning radius changes the values of C_1 becomes lesser and the value of C_2 becomes more. Calculation we conclude that for same wheel base and track width there is change in turning radius from 4.4m to 2.59m.

The model is designed considering the same wheelbase and track width. The model



is designed using the software CATIA V5.

Figure 37:Designed CATIA model

The model shown in figure is designed in CATIA by using the options surfacing, the model is designed considering four tires and four stub axles, here we are placing two steering set one at front and the other at the rear so the stub axle considered at rear wheels are exactly the same as front stub axles. There is a shaft connecting between the front steering box and the rear steering box and double wishbone suspension type is considered for suspension and only one degree of freedom is applied for the suspension motion, rest all the degrees are constrained.

Here two bevel gears are considered, one bevel gear is attached to the steering column of the front steering box and the other bevel gear is attached to the intermediate shaft. The input is given at the steering wheel by the driver which rotates the steering column, as steering column rotates the gear attached to it will rotate, the other bevel gear coupled with the bevel gear of steering column rotates in opposite direction, so with respect to the second bevel gear attached to the intermediate shaft.

The shaft rotates in the direction of the second bevel gear. The rear steering column is attached with the intermediate shaft also rotates as per the shaft such that the rear wheels attached to the rear steering column rotates as per the rear steering column, so the rear wheels rotates in opposite direction to the driver input to the steering wheel.

9.1 FINAL MODEL CREATING JOINTS:

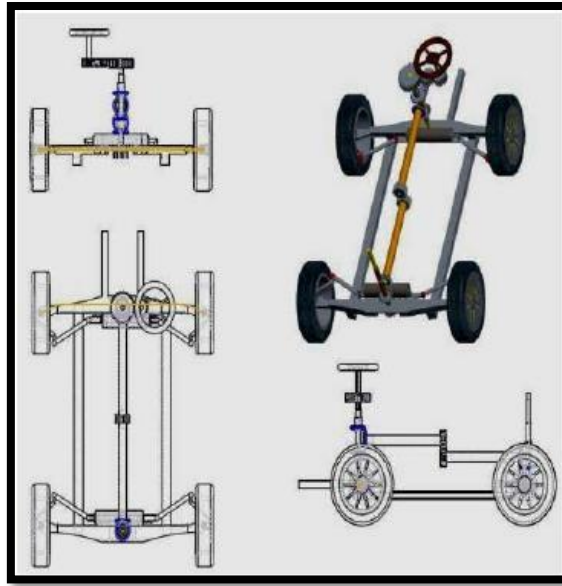


Figure 38: Final model after creating the joints

The final model after creating all the joints with respect to all parts. The joint given for front steering is replicated at the rear steering, there is bevel gear joint provided between steering column and intermediate shaft.

This intermediate shaft provides the rotation moment to the rear steering through rear body, the shaft gets the rotational moment from the bevel gear and this bevel gear gets the rotational moment from steering column.

Table 8.1 Joints connected to the parts

PART	PART	JOINT
Steering wheel	Rack body	Revolution
Steering wheel	Steering column 1	Hooke
Steering column 1	Steering column 2	Hooke
Steering column 2	Rack body	Cylindrical
Rack	Tie rod	Translation
Tie rod	Ball joint	Spherical
Ball joint	Wheel	Fixed
Wheel	Tire	Fixed

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 based on how to prove that the 4WS is better than 2WS in terms of turning radius

9.2 STIMULATION OF THREE MODE STEERING:

After creating all the joints, the simulation is carried out for the model. The motion is given to the steering wheel from that motion the vehicle turns with the help of the other parts and joints

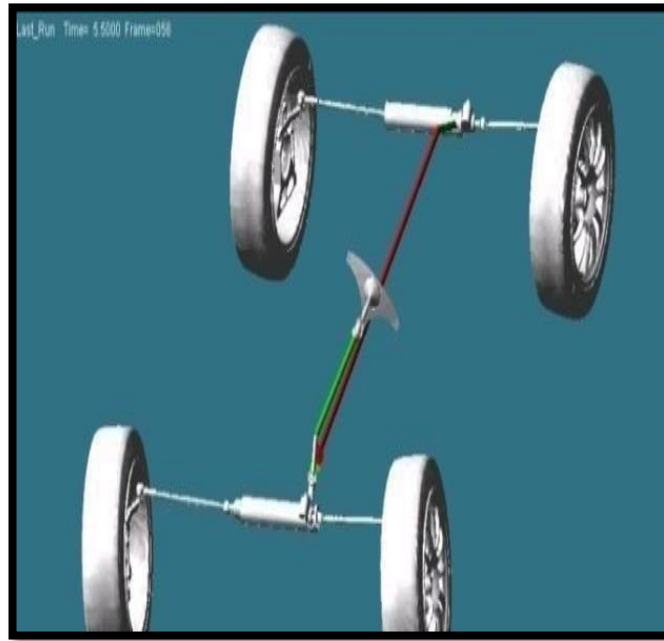


Figure 39: Simulation of three mode steering

. We conclude that all the four wheels are turning at an angle, the front wheels turn as per the steering wheel turns and the rear wheels turn opposite to the front wheels. As per the calculation and theory, the concept of four wheel steering is proved from the simulation.

9.3 DESIGN OF FRAME:

For building of prototype model, 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 prototype and 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 rear steering column is attached with the intermediate shaft also rotates as per the shaft such that the rear wheels attached to the rear steering column rotates as per the rear steering column, so the rear wheels rotates in opposite direction to the driver input to the steering wheel. We conclude that all the four wheels are turning at an angle, the front wheels turn as per the steering wheel turns and the rear wheels turn opposite to the front wheels

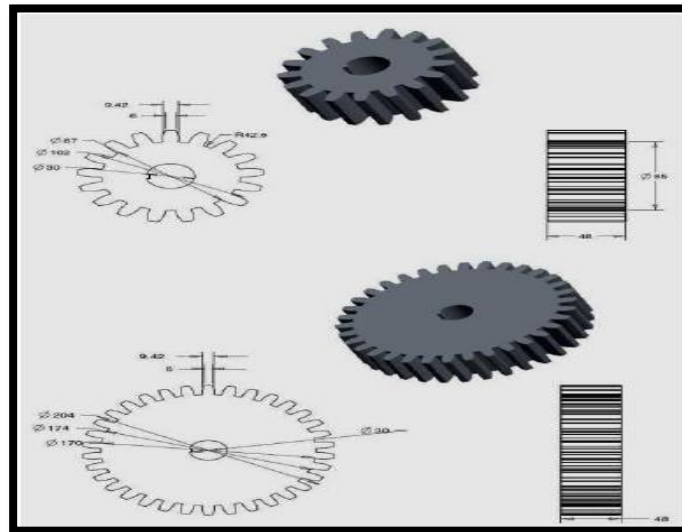


Figure 40: SPUR GEAR

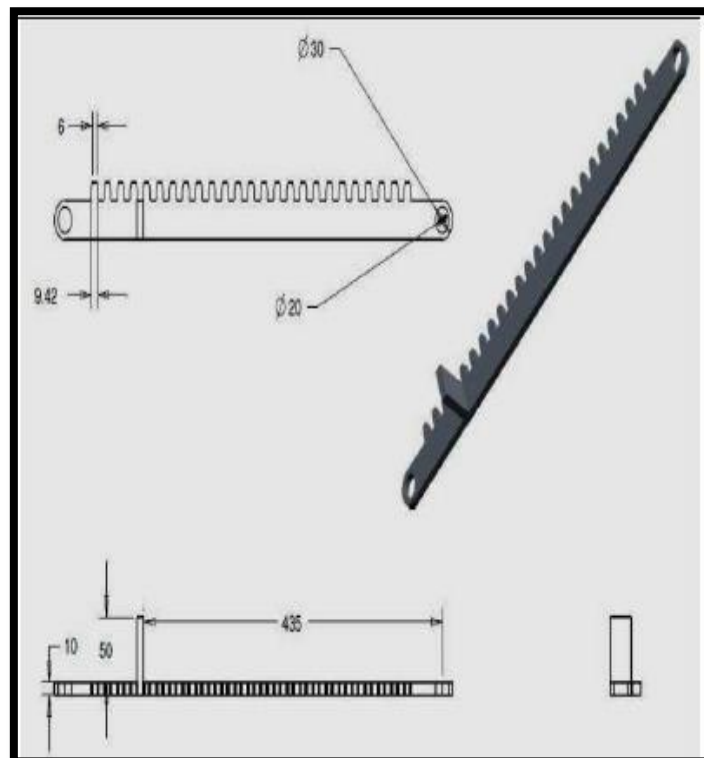


Figure 41: RACK

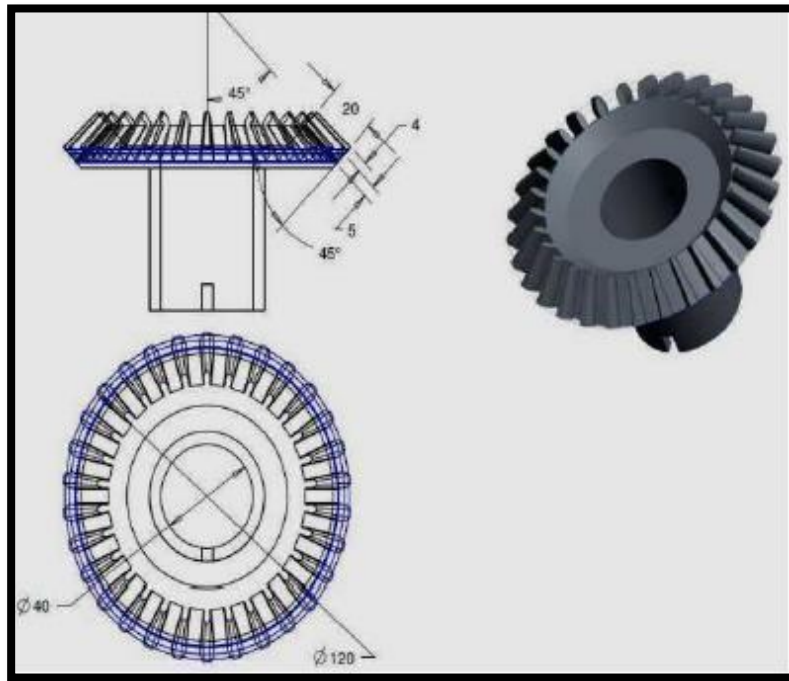


Figure 42: BEVEL GEAR

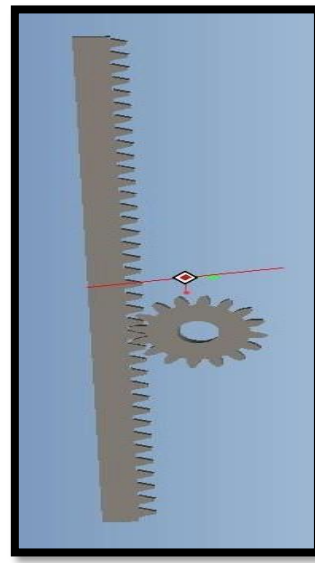


Figure 43: Gear meshing

7.1 FACTORS DETERMINING MATERIALS:

The various factors which determine the choice of material are discussed below.

7.1.1 PROPERTIES:

The material selected must possess the necessary properties for the proposed application. The various requirements to be satisfied can be weight, surface finish, rigidity, ability to withstand environmental attack from chemicals, service life, reliability etc.

The following four types of principle properties of materials decisively affect their selection

- Physical
- Mechanical

From manufacturing point of view Chemical. The various physical properties concerned are melting point, thermal Conductivity, specific heat, coefficient of thermal expansion, specific gravity, electrical conductivity, magnetic purposes etc.

The various Mechanical properties Concerned are strength in tensile, Compressive shear, bending, torsion and buckling load, fatigue resistance, impact resistance, elastic limit, endurance limit, and modulus of elasticity, hardness, wear resistance and sliding properties. The various properties concerned from the manufacturing point of view are,

- Cast ability
- Weld ability
- Surface properties
- Shrinkage

7.1.2 MANUFACTURING CASE:

Sometimes the demand for lowest possible manufacturing cost or surface qualities obtainable by the application of suitable coating substances may demand the use of special materials.

7.1.3 QUALITY REQUIRED:

This generally affects the manufacturing process and ultimately the material. For example, it would never be desirable to go casting of a less number of components, which can be fabricated much more economically by welding or hand forging the steel.

7.1.4 AVAILABILITY OF MATERIAL:

Some materials may be scarce or in short supply. It then becomes obligatory for the designer to use some other material, which though may not be a perfect substitute for the material design. The delivery of materials and the delivery date of product should also be kept in mind.

7.1.5 SPACE CONSIDERATION:

Sometimes high strength materials have to be selected because the forces involved are high and space limitations are there.

7.1.6 COST:

As in any other problem, in selection of material the cost of material plays an important part and should not be ignored.

Sometimes factors like scrap utilization, appearance, and non-maintenance of the designed part are involved in the selection of proper materials.

CHAPTER 6

RESULTS AD DISCUSSION

11.1

CALCULATIONS:

11.1.1. NORMAL MODE:

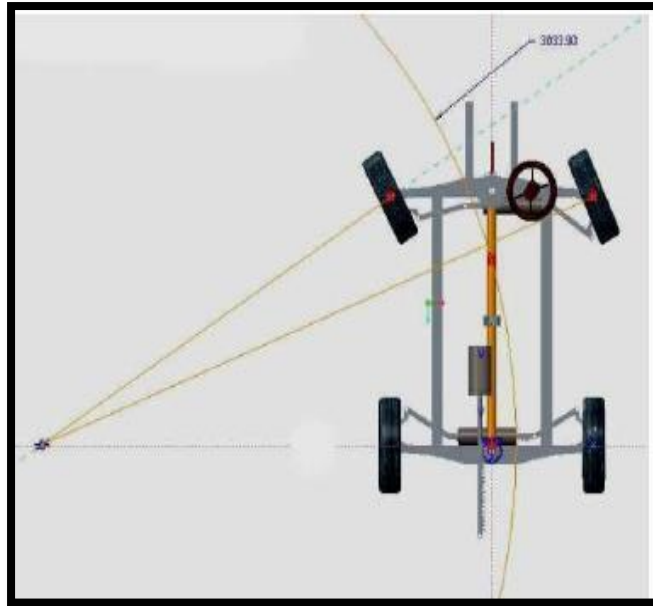


Figure 44:Normal Mode

Gravitational acceleration (G) =

9.81 m/s. Gross Weight (m) =

1350 kg.

Weight of vehicle (W) = $m * g$

=13243.5 N Radius of Wheel (rW)

=0.3556 m.

Radius of curvature(R)

= 3 m. Width of

Track(x) = 1.295 m.

Wheel Base (b)

=1.295 m.

Distance of C.G. vertically above the road surface (h)=

0.55 m. Distance of C.G. horizontally from rear wheel

axle (l)= 0.963 m. Linear velocity (V) = 26 Km/hr.

Mass moment of inertia of wheel (I_w) =0.8 Nm

Mass moment of inertia of rotating parts of engine (IE)

=13.5 Nm². Angular velocity of wheels or velocity of spin=20.8902 rad/s .

Gear ratio (G) =4

Angular velocity of rotating parts of engine

(w)=83.561 rad/s. Velocity of precession (wP)

=2.4761 rad/s.

Reaction on front wheels due to weight

=4924.128 N. Reaction on rear wheels due to weight =1697.622 N.

Reaction at front wheels due to centrifugal force(PiF=PoF) =

3921.41 N. Reaction at rear wheels due to centrifugal

force(PiR=PoR) =1351.93 N. Reaction at front wheels due to

gyroscopic effect(QiF=QoF) = 223.13 N. Reaction at rear wheels

due to gyroscopic effect(QiR=QoR) =223.13 N. Total reaction on front wheels (FF) = RiF-(PiF+QiF)=779.579 N.

Total reaction on rear wheels (FR) = RiR-(PiR+QiR) =122.556 N.

Table 11.1 TABULATION

RADII(M)	MAX SPEED(KM/H)	RADII(M)	MAX SPEED(KM/H)
3	26	60	120
10	49	70	130
20	69	80	139
30	85	90	147
40	98	100	155
50	110	106	160

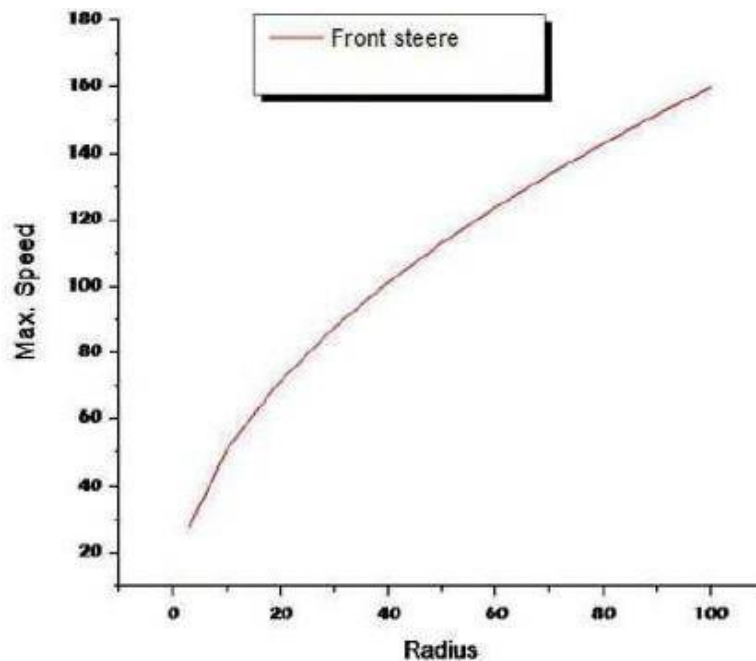


Figure 45: Graph of Radius vs Max speed

11.1.2. 2ND MODE OF

STEERING

Gravitational acceleration (G) = 9.81 m/s. Gross

Weight (m) = 1350 kg.

Weight of vehicle (W) = $m * g$

=13243.5 N Radius of Wheel (r_W)

=0.3556 m.

Radius of curvature(R) =

1.7868 m. Width of

Track(x) = 1.295 m.

Wheel Base (b) =1.295 m.

Distance of C.G. vertically above the road surface (h)=

0.55 m. Distance of C.G. horizontally from rear wheel

axle (l)= 0.963 m. Linear velocity (V) = 16 m/s.

Mass moment of inertia of wheel (I_W)= =0.8 Nm²

Mass moment of inertia of rotating parts of engine (I_E) =13.5

Nm². Angular velocity of wheels or velocity of spin (w_W)

=12.85554 rad/s. Gear ratio (G) =4

Angular velocity of rotating parts of engine (w_e)= =51.42214

rad/s. Velocity of precession (ω_P) = $V/R = 2.558444$ rad/s

Reaction on front wheels due to weight ($R_{if}=R_{OF}$)=4924.128N.

Reaction on rear wheels due to weight($R_{iR}=R_{oR}$)=1697.622 N.

Reaction at front wheels due to

centrifugal force($P_{iF}=P_{oF}$)=4183.322 N.

Reaction at rear wheels due to centrifugal

force($P_{iR}=P_{oR}$)=1442.225 N. Reaction at front wheels due to

gyroscopic effect($Q_{iF}=Q_{oF}$)=141.8757 N. Reaction at rear wheels

due to gyroscopic effect($Q_{iR}=Q_{oR}$)=141.8757 N. Total reaction

on front wheels(F_F)= $R_{if}-(P_{iF}+Q_{iF})=598.9295$ N

Total reaction on rear wheels(F_R)= $R_{iR}-(P_{iR}+Q_{iR})=113.5213$ N

Normal Steer Mode: Radius of curvature(R) =

3 m. Cross Steer Mode: Radius of

curvature(R)=1.7868 m.

%Reduction= $\frac{3-1.7868}{3} \times 100 = 40.44\%$

TABLE 11.2 TABULATION

RADII(m)	CROSS RADII(M)	MAX SPEED(KM/H)
3	1.7868	16
10	5.956	30
20	11.912	42
30	17.868	52
32	19.0592	54

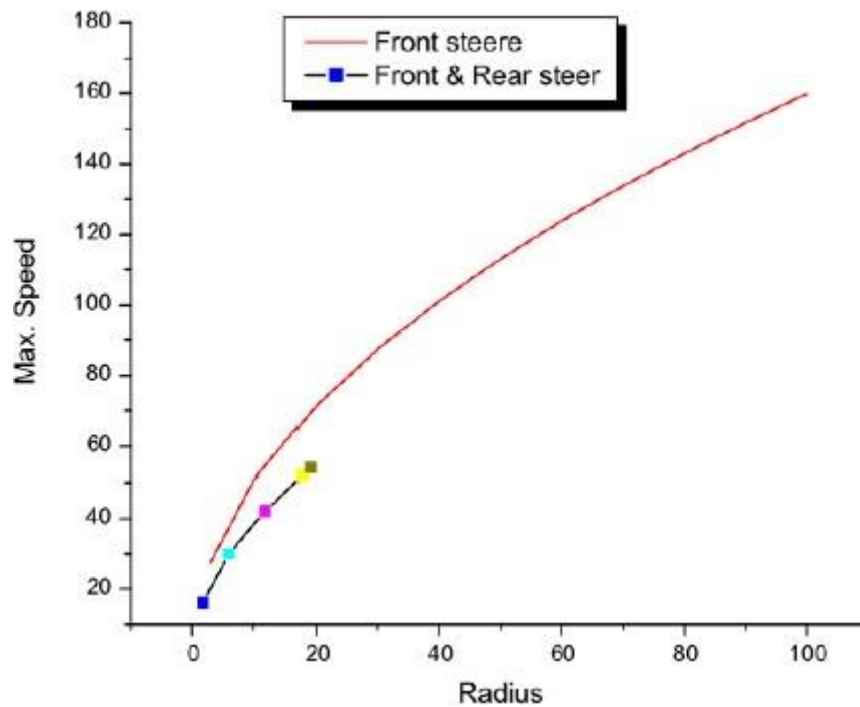


Figure 46: Graph of Radius vs Max speed

11.1.3. CRAB MODE:

Gravitational acceleration (G) =

9.81 m/s. Gross Weight (m) =

1350 kg./

Weight of vehicle (W) = $m * g$

=13243.5 N Radius of Wheel (rW)

=0.3556 m.

Width of Track(x) =

1.295 m. Wheel Base

(b) =1.295 m

Distance of C.G. vertically above the road surface (h)= 0.55

Distance of C.G. horizontally from rear wheel

axle(1)=0.963m. Linear velocity (V) = 95 km/hr.

Mass moment of inertia of wheel (IW)

=0.8 Nm^2 Mass moment of inertia of

rotating parts of engine (IE) =13.5 Nm^2 .

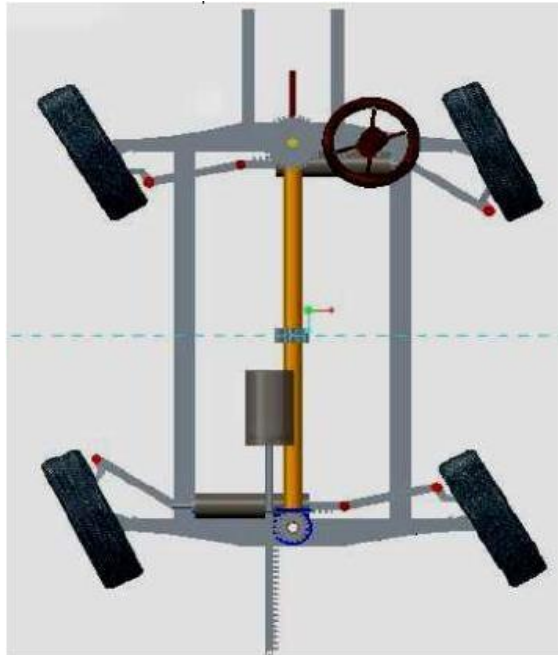
Angular velocity of wheels or velocity of spin

$(W_w)=76.324 \text{ rad/s}$ Gear ratio $(G) =4$

Angular velocity of rotating parts of engine

$(w_E)=305.3189\text{rad/s}$ $C_w =244.2551824 \text{ Nm}$.

$C_e= 4121.806203 \text{ Nm}$.



C
 $=4366.061385$
 Nm .

$W/2 =$
 6621.75 N .

$P/2 = C/2x =$
 1685.737987 N .

$R1=3238.857488 \text{ N}$.

$R2=11.41653844 \text{ N}$.

$R3= 6610.333462 \text{ N}$.

$R4= 6610.333462 \text{ N}$.

Table 11.3 Comparison for two wheel steer and four wheel steer

Turning radius	Four wheel steer	Two wheel steer

By calculation	2.59 m	4.4 m
By experiment	2.85 m	5.75 m

11.2 ADVANTAGES OF THREE MODES OF STEERING

- Easy maintenance.
- Mode change is easy.
- Implementation is easy.
- Used for easy parking in four wheelers.
- It is applicable for all four wheeled vehicles.

11.3 LIMITATIONS:

- The 4ws, due to construction of many new components, the system becomes more expensive.
- The system includes as many components (especially electronically) there is always a chance to get any the part inactive, thus the system become inoperative
- Suspensions in rear wheels demands considerable changes for proper working of the vehicle with varying load.

CHAPTER 7

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.

The project carried out by us made an impressive task in the field of automobile industries. It is very usefully for driver while driving the vehicle. This project has also reduced the cost involved in the concern. Project has been designed to perform the entire requirement task which has also been provided.

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