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Design and Fabrication of Four Mode in Four-Wheeler Steering Mechanism

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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 duringalanechangemaneuverinthreetypeofconditionwhichislowspeed 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.

I. 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 bywhich rail tracks combined together with railroadswitchesprovide 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 thesteeringcolumn,whichmay containuniversaljointstoallowittodeviatesomewhatfrom 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 ofdifferent modes of steering, some kind ofmeans mustbeprovidedformaintainingthewheels synchronizedwhenshiftingfromonemode 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.

A. Project Overview

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 ofthevehicle. The directionofsteeringtherearwheelsrelative tothefrontwheelsdepends 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.

2) Disadvantages:

- Itisvery expensive.
- Itiscomplexindesign.
- Itwillbeeasilyputoutofadjustment.

3) Proposed System:

Inour 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-wheelsteering, I meanthat ina vehicle havingtwo pairs ofdirigiblewheels 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.

4) Advantages

- Easymaintenance.
- Mode changeiseasy.
- Implementationiseasy.

B. Working Principle

Figure1:Gearmesh:

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

- Frontwheelsteer
- Bothfrontandrearwheelsteerinsamedirection
- Bothwheelsinoppositedirection

Whenthelocknutisremoved,thesteeringoperationiscarriedoutinnormal 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 gearsare engaged and the steering ofrear wheel is ensured and is in same directionas that ofthe front wheels. When the gear arrangement is moved to other side, the spur gear disengages andthebevel gearisengaged.Duetobevelgeararrangement,therearwheel steersin opposite direction to the front wheel. This results in third mode steering

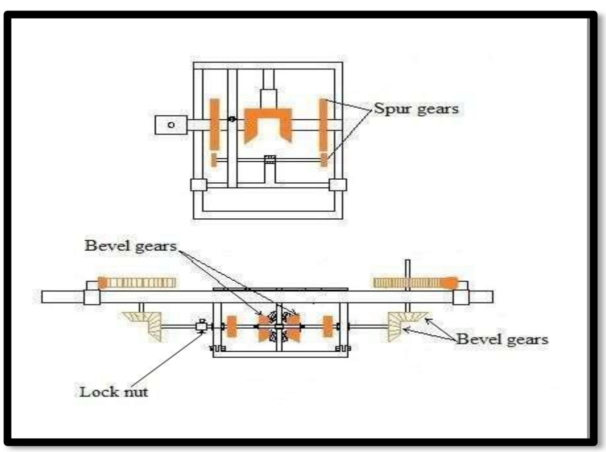

Figure2:WORKINGPRINCIPLE

1) Front Wheelsteering:

Ina front wheel, steering, onlyfront wheels steer, and ina rear wheel, steering only rearwheelswill steer to getturning. In a four-wheelsteeringsystemat lowspeeds, the front wheels and rear wheelsare out of phase for lowturning radius. However athighspeeds, The front and rear wheels should be in phase to increase the stability of a vehicle.Sothelocknutisremoved,the steeringoperation iscarriedoutinnormal condition.That is only front wheels steer.

Figure3:1STMODEOFOPERATION

2) Both Frontandrear Wheelsteer 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 ofrear wheel is ensured and is in same directionas that of the front wheels.

Figure4:2ndModeofSteering

3) Both Wheelsinoppositedirection

When the gear arrangement is moved to other side, the bevelgear disengages and the bevel gear gets engaged. Dueto spur gear arrangement, the rear wheel steers in oppositedirection tothefront wheel. This results in third modesteering. Threesteering modes canbe changed asneeded whichassists in parkingat heavytraffic conditions, when negotiatingareaswhere short turning radius is needed and in off road Driving.

Figure5:3RDMODEOFOPERATION

C. Problem Definition

Nowadays all vehicles uses two wheel steering system, but the efficiency of thetwo-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 vehicleto be higher wheelbase and track width as it givesgood 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. Inthis 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 mechanismis built which turns the rear wheels opposite to the front wheels.

II. LITERATUREREVIEW

Lohith [I] shows that the Four-wheel steering is a seriouseffort on the part ofautomotive designengineersto providenear-neutralsteering. Incertaincaseslikelowspeedcornering, 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 drawnout ofphase to the front wheels. Inorder 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]explainsthataFourWheelsteering(4WS)Systemisalsoknownas"Quadra SteeringSystem".Sobothfront as wellasrearwheel scan be steered accordingtospeedof the vehicleandspace available for turning. Quadra steer system will give full sizevehicles greatereasewhiledrivingatlowspeed,andimprovesstability,handlingandcontrolathigher speed.Quadrasteeringsystemworksin followingthreephasesNegativephase,Neutralphase, Positivephase.Itenablesthecarto be steered intotighterparkingspacesand makesthecar morestableatspeed(lessbodyroll).Itmakesthecarmoreefficientandstableoncornering, easier andsaferlaneschangewhenon motorways. Thesteeringsystemallowsthe driverto guidethe moving vehicleontheroadand turnit right or left asrequired.

Jeong[3]describesthevehiclemodelinganddynamicanalysisoffourwheelsteeringsystem. 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 onthe speed and yaw rate ofthe vehicle performance.

Sathyabalan[4] shows that the fabricated the four wheel steering can operate three mode operation. The project is to steerthe vehicle according to the requirement. The four wheel steeringis morerequired incriticalroads and in desert roads. Inthis, implementing three steeringmodes in a single vehicleand the modes can bechangedas 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 foraUtilityVehicle(UV)thatisoriginalequippedwitha 500ccinternalcombustionengine. The designedpowertrainisconsistedoftwo5kwbrushlessDCmotors(BLDC)withtheassociated 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_ToguaranteeAMTgear-shiftingquality,thegear-shiftingmapswasappliedingear changeprocess.Thepowersplitstrategydesignforthe4WDEVwasbasedonslidingmode algorithm, it was shown through numerical simulation that slip ratio on each wheel can be controlled within an optimal value in ECE40 drivepattern.

Gao[6]showsthekinematicmodelsofplanetarygearsetandsteering geararеestablished,based on the analysis of the transmission mechanism of angle superposition with Active Front Steeringsystem(AFS).Acontrollerofvariablesteeringratiofor ActiveFrontSteeringsystem 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 advantageofvariablesteeringratio function,alsoshowthatthedrivingcomfortisimproved at low speed especially, due to the Active Front Steering system alters the steering ratio according to the drivingsituation.

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 maximizedspaceforabigandstrongathlete.The,frontdrivenbicycleshavethedisadvantage thatthefrontdrivinginducesunwantedsteeringandthatthefrontalareaofthebicyclecannot bereducedanyfurther.Asolutionwouldberear-wheelsteering.Acommonthoughtisthata rear-wheelsteeredbicyclecannotbelaterallyself-stable,andthereforehardtocontrol.

Onecan design a rear-wheel steered bicycle which shows a stable forward speed range. Computer simulations demonstratethatthebicyclecanbestabilizedbyaddingahumancontrollermodeltothebicyclemodel.Forasetofexpectedlateralperturbations(sidewindperturbations)it is shownthatridersteertorquestayswithinhumanbounds,bothinmagnitudeandinfrequency. Pushkin Gautham [8] shows that Selectable All Wheel Steering is a relatively new technologythat improves maneuverabilityin cars, trucksand trailers. All wheel steering is used forparking 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 ofAWS(AllWheelSteering).Theengagementanddisengagementofthefourwheelssteering is done as per the driver requirement. Thisprovidesthe benefits ofboth two wheeland four wheelsteer.Thus,canbeusedasfrontwheel steerinlongstraightrunsand canbeusedasall wheel steer when sharp and close turns are needed. The Mechanically Operated SAWS arrangementisthemostcompactandcosteffectivesystemswhichcanbeinstalledinanATV without making changes tofour wheel mechanism.

Deepak[9]carriedoutdesignandanalysisofathreewheeledvehiclethat hassteeringonboth 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 determinedthat the turning radius of thewheelisobtainedbyusingallwheelssteeringmechanismanditisrelativelysmallerthan actualturningradius.Theequivalent stressvalueswerealsodetermined forsafe design.

Bhishikar[10]showedthatstandard2WheelSteeringSystem,therearsetof 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 canbeguidedathighaswellaslowspeeds.Production carsaredesignedto 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 undervaryingoperatingconditions.Insituationslikelowspeedcornering,vehicleparkinganddrivingincityconditionswithheavytrafficintightspaces,drivingwouldbevery difficult due to a sedan's larger wheelbase and track width. Hence there is a requirement of a mechanism which result in less turningradius.

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 changedas needed. Four wheel steering system vehicles proved dynamic results through doublelane 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 arrangedthat 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 byan eccentric on the input shaft. A shortshaft in integral with the planet and is offset fromthe 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 ofthe input shaft rotatesthe 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 thatthe rear wheels are set in a straight ahead position.

As the input shaft and planet are rotated towards the full-lock position, the strokerod attains maximum displacement and consequently a corresponding movement ofthe 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.

MAZDA4WS SYSTEM [12]The rear wheels in this system are steered by a hydraulically operated power unit, which is electronically controlled in accordance with the steeringwheel angle and vehiclespeed. The Mazda4WS layout is more complicated thantheHonda 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-aheadposition.

Itisdeterminedthattheturningradiusofthewheelisobtainedbyusingallwheelssteering mechanism anditisrelativelysmallerthan actualturning radius.The equivalent stress valueswere also determined for safedesign.. Afixed annulus is meshed with a large planet gear, which is driven byan eccentric on the input shaft.

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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 wheelsare turnedtothestraight-aheadposition.Above thisspeedtherearwheelsaresteeredin the same direction as the front wheels with an angle limited to 5 degrees.

Thefunctionsofthesecomponentsinsteeringtherearwheelsareasfollows:

- Sensorstomeasurevehiclespeed.
- Steering phase control unit conveys to the hydraulic control valve the requiredstroke direction of movement. (Hi) Electric stepper motor alters the yoke angle and bevel gear phasing in accordance with the signals received from the ECU.
- Rear steering shaft provides the positionofthe front wheels to the bevel gear in the steering phase control unit.
- 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 directionof thecurveandthuscurbon theefficiency of thesteering.Normallythissystem 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 byonly2 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 twowheel steeringsystem,the advantages offered bya four-wheel steering system include:

- Superiorcorneringstability.
- Improvedsteeringresponsivenessandprecision.
- Highspeedstraight-linestability.
- Notableimprovementinrapidlanechangingmaneuvers.
- Smallerturningradiusandtightspacemaneuverabilityatlowspeed.
- Relativewheel anglesandtheircontrol.

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, andmomentummoves thecar straight ahead.Steering input causesthe frontwheelsto 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 swaysastherearwheelsattempttokeepupwiththecorneringforcesalreadygenerated 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 tryto adjust by reversing the same forces developed bytheturn.Asthesteeringisturned,thevehicle bodyswaysastherearwheelsagaintry 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 allfour wheels are steering the vehicle. As with two wheel- steer vehicles, tire grip holds the four wheels on the road.

.However,whenthedriverturns thewheelslightly, allfour wheelsreact tothesteering input, causing slip angles to form at all four wheels. The entire vehicle moves in one directionrather thanthe rear half attempting to catchup to the front. There is also lesssway 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 ofsteering 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 directionto that of front wheels. This also simplifies the positioning of the car in situations such as parking in a confined space.

Sincetherearwheelsare madetofollowthepathontheroadtakenbythe frontwheels, the rear ofa four-wheel steering car does not turn inthe 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 laneson a high speed road. The elimination ofthe centrifugaleffect 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.

A. 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 iscommon in foreign countries and is prettyrelevant 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.

Moreovertosuccessfullyparkthevehiclewithoutincurringanydamageatleast

1.75 times the length ofthe car must be available for parking a two wheeled steer car. As can be seen clearlythecar requires just aboutthesame length as itselfto 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.

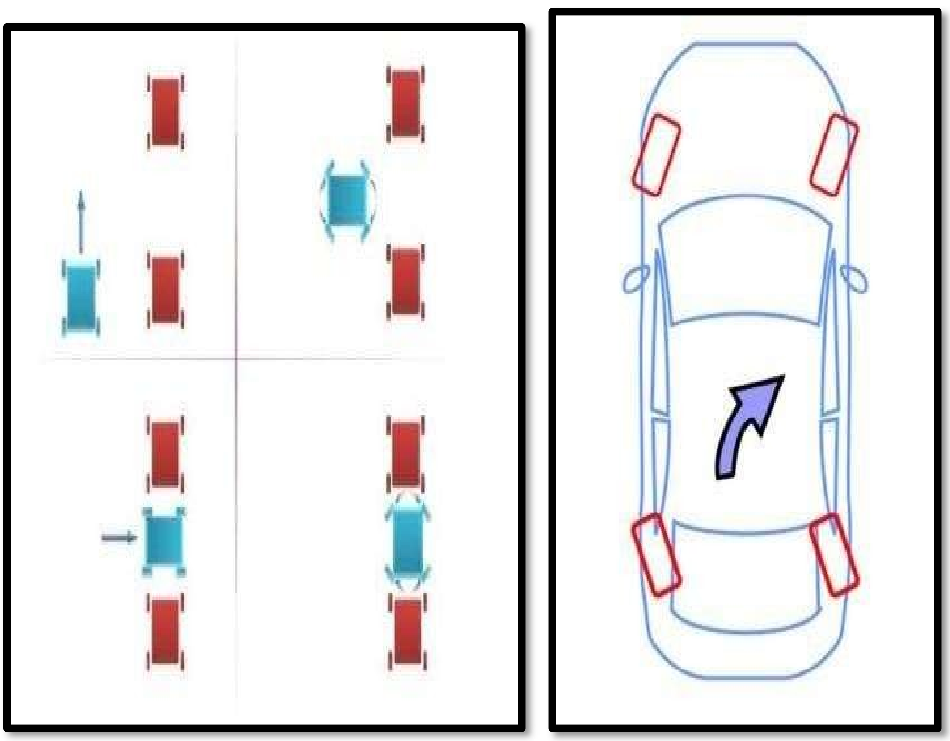

Figure6:Parallelparkingmaneuvers

B. Highspeedlanechanging:

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 figurethe vehicle can turn with hardly any space requirement with a single steering action andalso resume without any corrective inputs. Thus, it also acts as a driver aid helpingrelatively inexperienced drivers make quick lane changes even at high speeds.

Thecompany HondaPreludemanufacturedthefirstfour-wheelsteeringcarand 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

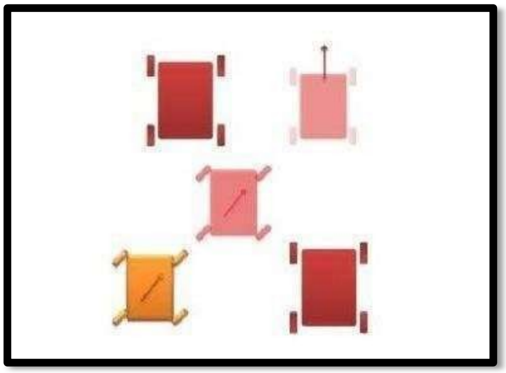

Figure7:High-speedlanechangemanoeuvres

This means more steering angle input is required to perform agradualturn, 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 thecar a go-kart like feel during tight manoeuvres.

The observed effect while driving might be best imagined as a variable effective wheelbase, froma long wheelbase at smallsteering 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 oftransient 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.

C. 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 rearaxles of buses,asthe rear axle isa drivenmember 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 ofparking in depots. Thesteering mechanism might haveto bechanged,however, in this case. However, the two steering modes described in this project canbe successfully implemented in heavy vehicles, as it described in a similar four-wheel steered trailer-bus.

Figure8:TrailerBuswithFour-WheelSteering

III. MATERIALSANDCOMPONENTS

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

- Rackandpinion
- Bevelgear
- Spurgear
- Steering
- Wheel
- Hingejoint

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.

A. Gear

Gearorcogwheelisarotatingmachineparthavingcutteeth,orcogs, which mesh with another toothed part to transmit torque, in most cases with teeth on theone 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.

Thegearsinatransmissionareanalogoustothewheelsinacrossedbelt pulleysystem. Anadvantage ofgears 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 thetorques 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.

B. 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 dependupon 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 lubricationrequirements may impose a higher operating cost.

Figure9:V-BELTDRIVE

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C. Types

1) External vs Internal Gears

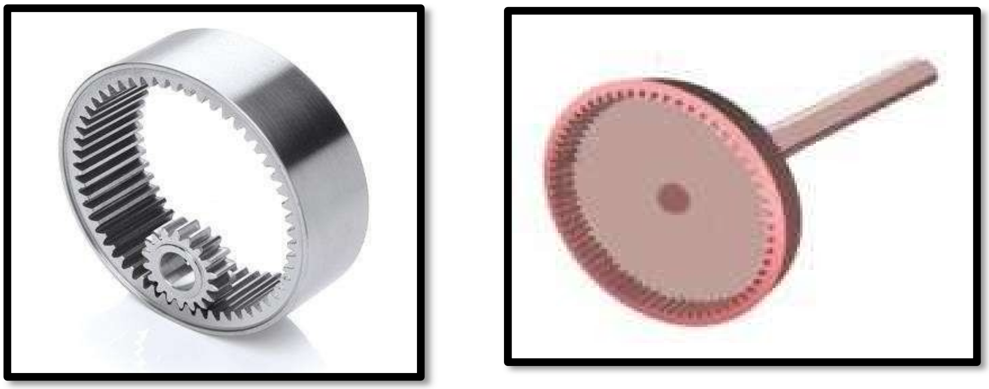

Figure10ExternalvsInternalgear

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 exceeding90 degrees. Internal gears do not cause output shaft direction reversal.

2) SPURGEAR:

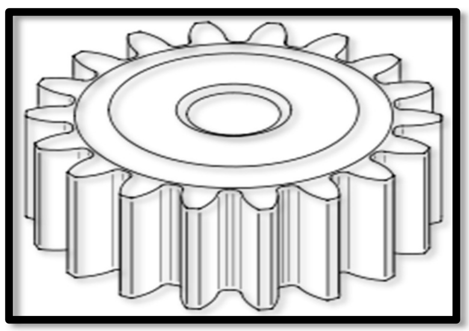

Figure11:Spurgear

Spur gears or straight-cut gears are the simplest type of gear. They consist of a cylinder or diskwiththe teeth projectingradially,and although they are notstraight-sided in form (they are usually of special form to achieve constant drive ratio, mainly involute), the edgeofeach toothisstraightandaligned parallel to theaxisofrotation. Thesegears can be meshed together correctly only if they are fitted to parallel shafts.

3) HELICALGEAR:

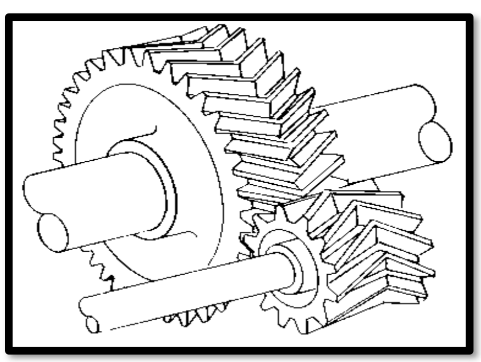

Figure12:Helicalgear

Helical or "dryfixed"gearsoffer 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 canbe meshed in parallel or crossed orientations. The former refers to whenthe shafts are parallel to each other; this is the most common orientation. In the latter, the shafts arenon-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 moresmoothly and quietly.Withparallel helical gears, each pair ofteeth firstmake contact at a single point at one side of the gear wheel; a moving curve of contact then grows graduallyacrossthetoothfacetoamaximum thenrecedesuntiltheteethbreakcontactat a single point on the opposite side. In skew gears, teeth suddenly meet at a line contact acrosstheirentirewidthcausingstressandnoise.Spurgearsmakeacharacteristicwhine 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.

Adisadvantageofhelicalgearsis aresultantthrust along the axis ofthe 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) SKEWGEARS:

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. Therelationship betweenthetwo shaftsisactuallydefinedbythehelixangle(s)ofthetwoshafts and the handedness.

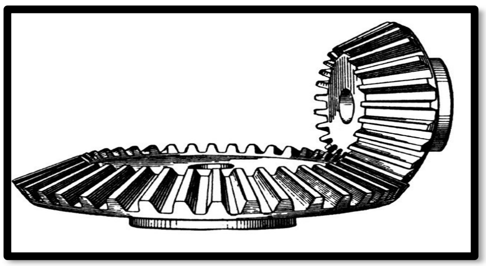

Figure13:Skewgear

$E = \beta_1 + \beta_2$ For gears of the same handedness $E = \beta_1 - \beta_2$ For gears of opposite handedness

Where β is the helix angle for the gear. The crossed configuration is less mechanicallysoundbecausethereisonlyapoint contactbetweenthegears,whereasintheparallel 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 toas having a right-handed helix anda left-handed helix of equalangles.

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. Forshafts crossed at right angles, thehelix angles are of the same hand because they must add to 90 degrees.

5) DOUBLEHELICAL:

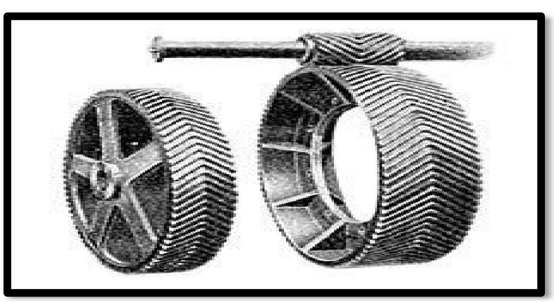

Figure14:Doublehelicalgear

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.

Forbothpossiblerotationaldirections,thereexisttwopossiblearrangementsfor the oppositely-oriented helical gears or gear faces. One arrangement is stable, and the other isunstable. Ina stableorientation, thehelicalgear faces areorientedso that each axialforce 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 arrangementgenerates anetforcethatmay leadtodisassembly of thegeartrain, whilethestablearrangementgeneratesanetcorrectiveforce.

6) BEVELGEAR:

Figure15:BEVELGEAR

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 axesalso 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 withequal numbers of teeth and shaft axes at 90 degrees are called miter gears.

7) SPIRALBEVELGEAR:

Figure16:Spiralbevelgears

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), KlingelnbergCyclo-Palloid(Epicycloide with constant tooth depth) or KlingelnbergPalloid.
Spiral bevel gears have the same advantages and disadvantages relative to their straight-cut cousins as helical gears do to spur gears.

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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 conedistance. Innerspiral angleisthespiralangleofabevelgearattheinnerconedistance.

8) HYPOID GEAR:

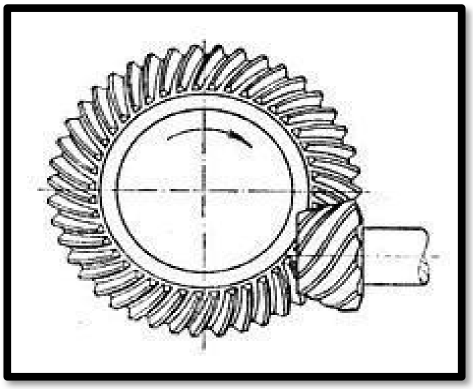


Figure17:Hypoidgear

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 facthyperboloids 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, contactbetween hypoid gear teeth maybe even smoother and more gradual thanwithspiral 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 teeththanaspiralbevelpinion.withtheresultthat gear ratiosof60:1 and higher are feasible using asingleset ofhypoid gears. Thisstyle ofgear is most common in motorvehicle 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 is generates more noise and vibration than a hypoid does. Bringing hypoid gears to market for mass-production applications was an engineering improvement

9) CROWNGEAR:

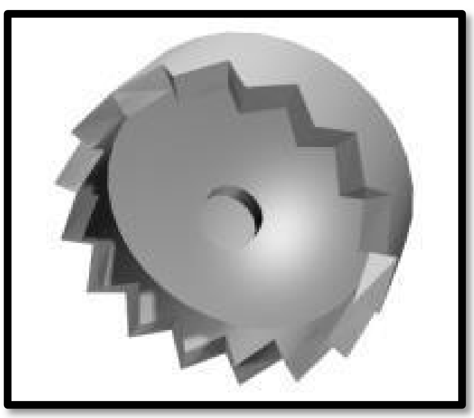
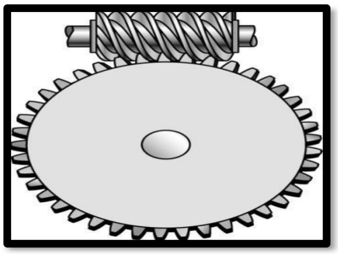


Figure18:Crowngear

Crowngearsor contrite gears areaparticular form ofbevelgear whoseteethproject atrightanglestotheplaneofthewheel; intheirorientationtheteethresemblethepoints on a crown. A crown gear can only mesh accurately with another bevel gear, althoughcrown gears are sometimes seen meshing with spur gears. A crown gear is also sometimes meshed with an escapement such as found in mechanical clocks.

10) WORMGEAR:



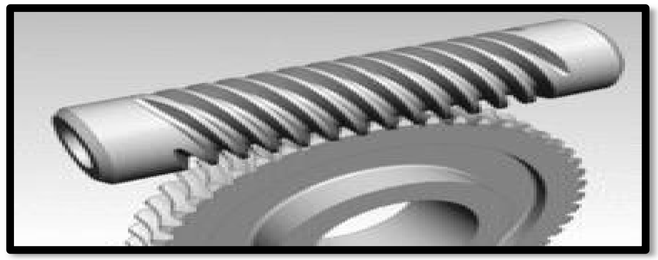


Figure19:Wormgear

Worms resemble screws. A worm is meshed with a worm wheel, which lookssimilar to a spur gear.Worm-and-gear sets are a simple and compact way to achieve ahigh torque, low speed gear ratio. For example, helical gears are normally limited to gear ratiosof 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 itscrew like qualities. The distinction betweena worm and a helical gear is thatleastone toothpersists for a full rotationaround the helix.Ifthis occurs,itis a 'worm'; if not, it is a 'helical gear'. A worm may have as few as one tooth. Ifthat tooth persists for several turns around thehelix, the worm appears, superficially,tohave more than onetooth, but what one in fact sees is the same tooth reappearing at intervals along the length of the worm.Theusualscrewnomenclatureapplies:aone-toothedwormiscalledsingle thread or single start; a wormwith more thanonetoothis called multiplethread 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 thewormandthenhavethemechanismholdthatposition.Anexampleisthemachine 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 ofthe gear is modified to achieve more intimate contact by making both gears partially envelop each other. This is done by making both concave and joiningthem at a saddle point; this is called acone-drive. Or "Double enveloping".Worm gears can be right or left-handed, following the long-established practice for screw threads.

IV. STEERING MECHANISM AND FABRICATION

A. BRIEF DESCRIPTION OF STEERING PARTS

1) SteeringWheel:

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.

2) Steering Column:

This is a hollow steel pipe in which steering shaft is housed. One end ofthe pipe is fixed onthesteering box, whilethe other end is usuallyheld withthe help ofbracket under the instrument panel.

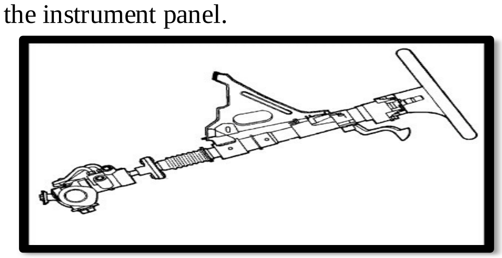


Figure20:STEERINGCOLUMN

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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.

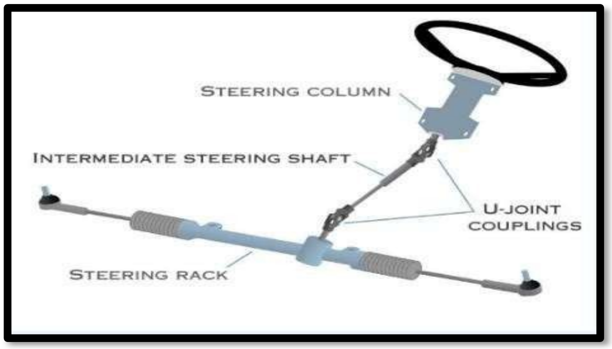

Figure21:STEERINGSHAFT

4) Steering GearBox

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.

5) Droparm

It is forged out ofgoodqualitysteel. 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.

B. STEERING PRINCIPLES AND COMPONENTS

1) AckermannSteeringMechanism

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 theprinciple is sound for low speed manoeuvres.

2) SteeringRatio

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 generallyusedwithpresentdaysteeringgearsvaryfrom about12:1forcarstoabout35: 1 for heavy vehicles. An average overall ratio usually gives about one and half complete turns ofthe steering wheel each side of mid position to applya full lock of 45 degrees each way on the wheels.

3) TurningCircle

Theturningcircleofa car isthe diameterofthecircledescribedbytheoutsidewheels when turningon full lock. There is no hard and fast formula to calculate the turning circle butan approximate value can be obtained using the formula:

$$\text{Turningcircleradius} = \left(\frac{\text{turn}}{2}\right) + \left(\frac{\text{wheel base}}{\sin(\text{averagesteerangle})}\right)$$

4) SteeringGeometry

When a car is moving along a curve, all its wheels should roll trulywithout anylateralslip. This can be achieved ifthe axis ofall four wheels intersects at one point. This point will be thecentre about which the vehicle will be turning at that instant. Figure shows thesteering 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 shouldcoincide.

5) WheelAlignment

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

Awheelissaidtohavedirectionalstabilityorcontrol ifitcan:

- Runstraightdownaroad
- Enterandleaveaturneasily
- Resistroadshocks

Factorspertainingtosteeringgeometryare:

6) King-pininclinationorsteeringaxleinclination:

Theanglebetweentheverticallineand centreofthe kingpinor steering axle, whenviewed from the front of the vehicle is known as king pin inclination orsteering axle inclination.

- Ithelpsthecartohavesteeringstability
- It makes the operation of the steering quite easy particularly when the vehicle is stationary.
- Ithelpsin reducingthewearon tyre

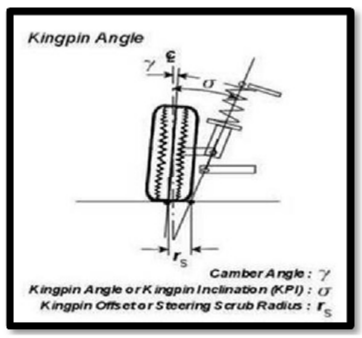

Figure22:kingpinangle

7) Includedangle:

The combined camber and king pin inclination is called included angle. It determinesthe 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

- Ifthepointofintersectionabovetheground,thewheeltendstotoe-in
- If itisbelowtheground,thewheeltendstotoe-out
- Ifit 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.

8) Caster:

In addition to being tilted inward toward the centre of the vehicle, the king pin axis mayalso 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 centreline.The caster anglein modern vehiclerangefrom 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. Whenthewheeltrailsthelineofweightthatmovesinthe same directionasthevehicleit 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.

Whenthecasterat thetwo wheelsarenot equal, thetendencyto toe-inat thewheel with the larger caster will be more which will cause the vehicle to pull constantly towards the side of the wheel with lesser caster.

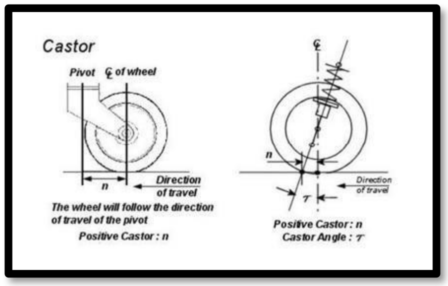

Figure23:CASTOR

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. Purposeofcamberis to prevent thetopof thewheels from tilting inwardstoo 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 willjustbringthewheelstoaverticalposition.

- Positivecamber:Whenupperpartofwheelisoutside.
- Negativecamber:Whenupperpartofwheelisinside(towardsthecentrelineofthecar).

10) Toe-in:

Thefrontwheelsareusually turned in slightlyin front so thatthe distance betweenthe 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.
Theactualamountoftoe-inisusually rangesfrom3-5mm.

- Itensuresparallel runningofthefrontwheels
- It stabilizessteering
- Itpreventssideslippingandexcessivewearofthetyres
- It also serves to offset the small deflections in the wheel support system which comes out then the vehicle is moving forward.

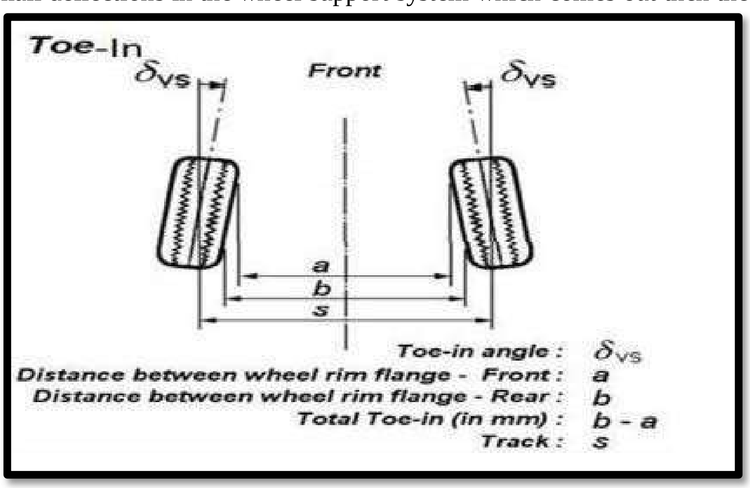

Figure24:TOE-IN

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.

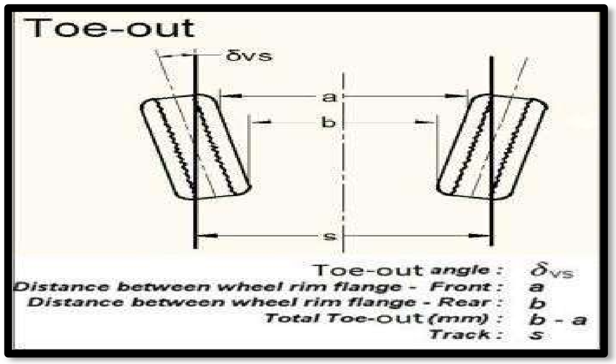

Figure25:TOE-OUT

C. Vehicle Dynamics And Steering

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

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.

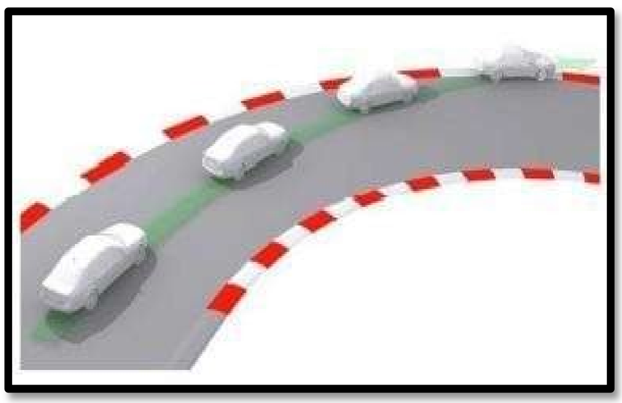

Figure26:UNDER-STEER

2) Over-steer:

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

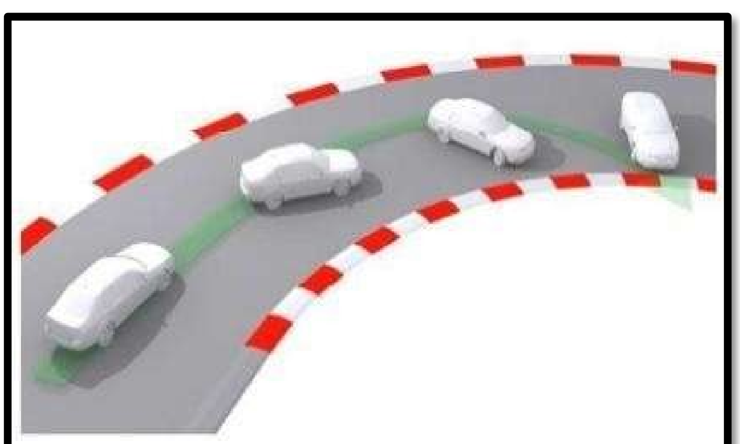

Figure27:OVER-STEER

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3) Neutral-steer or Counter-steering:

Counter-steering can defined aswhen the slip angle of front wheels is equal to slip angle of rear wheels.

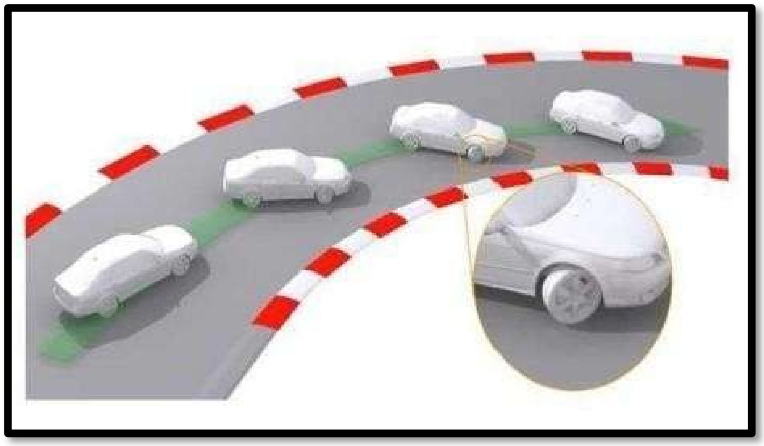

Figure28:Neutral-Steer

4) Pitmanarm

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 pitmanarms.Newercarsandunibodylight-duty trucks typically all use some derivative of rack and pinion steering.

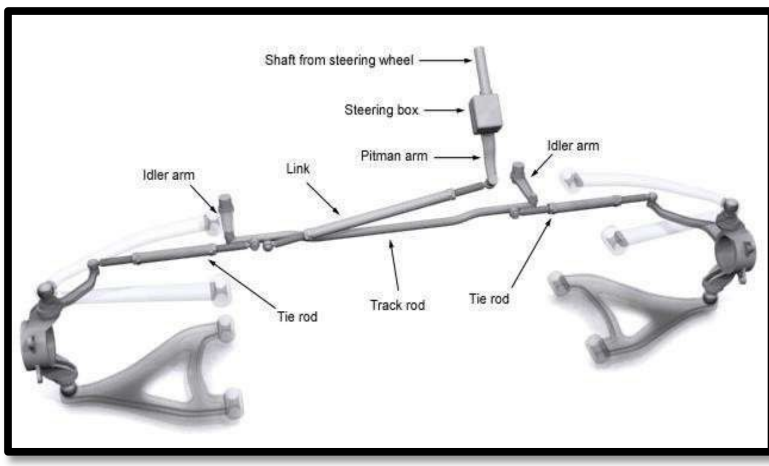

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Figure29:PitmanArmType

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 tothe 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.

Mostofthesteeringboxmechanismsthatdrivethepitmanarmhavea'deadspot'inthe 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,priceandweight. Thefollowingarethefourbasictypesofsteeringboxusedin pitman arm systems.

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5) RACKANDPINION

This isby 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.

Ina rackand pinionsystem,the trackrodisreplacedwiththesteeringrackwhich is a long, toothed bar withthe tie rodsattached to each end. Onthe end ofthe steering shaft there is a simple pinion gear thatmeshes with the rack. Whenyou 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 pinionsystem(left) aswellas a close-up cutawayofthe steeringrack itself (right).

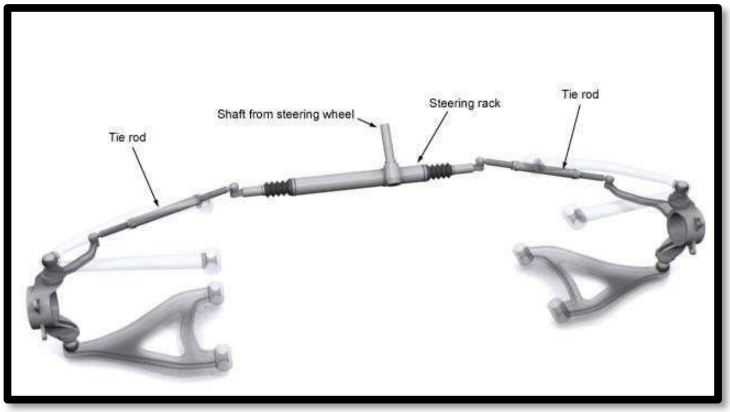


Figure30:RackandPinionType.

6) Variable-RatioRackandPinionSteering

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

Inthe middle, theteeth are spaced close together to give slight steering for the first part ofthe 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 sameturn ofthe steering wheel towards full lock.

D. Recirculating Ball Rack Ands Ector

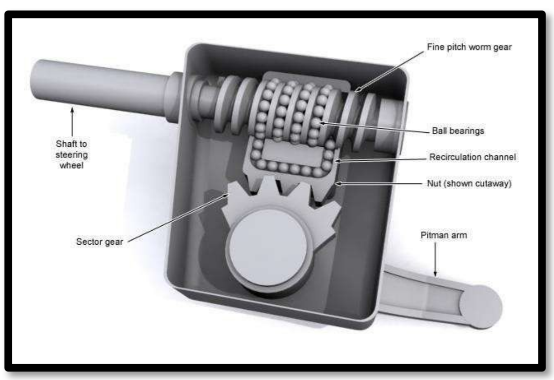


Figure31:RackandPinionType.

This is by far the most common type of steering box for pitman arm systems. In a recirculating ball steering box, thewormdrive has manymore 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 wormdrives 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 crossshaft just likein thewormand sector mechanism.

This systemhas much less freeplay orslackin itthantheotherdesigns,hencewhyit'susedthemost. Theexample belowshows arecirculatingballmechanism withthenutshownincutawaysoyoucanseetheball bearingsandtherecirculationchannel.

E. Worm And Sector

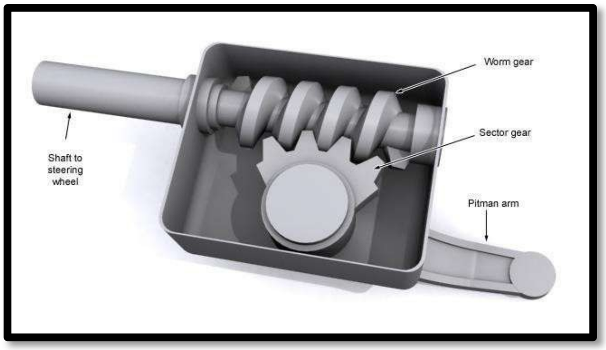


Figure32:WormandSector.

In this type ofsteering box, the end ofthe shaft fromthe steering wheel has a worm gearattachedtoit.Itmeshesdirectly withasectorgear(socalledbecauseit'sasectionof afullgear wheel).Whenthe steeringwheelisturned, theshaftturnsthe wormgear,and thesector gear pivots around its axis as itsteethare moved along the worm gear. The sector gearis mounted onthe crossshaft whichpassesthrough the steering boxand outthebottom 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.

F. Worm And Roller

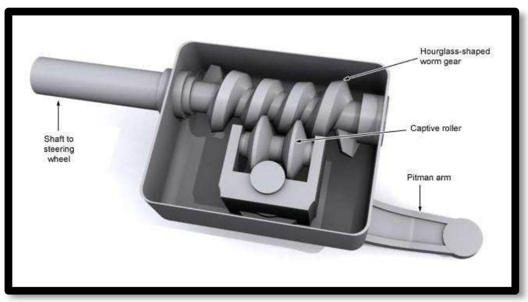


Figure33:WormandRoller.

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 wormgear, there is aroller instead.The roller is mounted on a roller bearing shaft and is held captiveon 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

G. CAMAND ROLLER

Figure34:CamandRoller

Cam and lever steering boxes are very similar to worm and sector steering boxes. As thewormgear is turned, the studs slide along the camchannels 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.

V. DESIGN CALCULATION AND MODEL

A. CALCULATIONFORSTEERING ANGLE:

Calculationforsteeringanglesfortheturning radiusof 4.4m. Fromthe benchmark vehicle, we know that turning radius is 4.4 m.

Weknowthat

$R^2=a^2+R^2$... (1)

Where

R = Turning radius of the vehicle. a_2 =DistanceofCG fromrearaxle.

R_1=Distancebetweeninstantaneouscenterandtheaxisofthevehicle.

Tofinda2:

$W_f=(W*a_2)/L$... (2)

Where

W_f = Load on front axle. W = Total weight ofcar. L = Wheelbase.

Sofromequation2and1

a_2 = 1305 mm. R_1=4202mm.

TOFINDSTEERINGANGLE:

Fromtest we foundthat the inner angle offront tire is, $\delta_{if} = 25.6^0$.

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

$C_1+C_2=L$..(4)

Where

C_1 = Distance of instantaneous centre from front axle axis. C_2=Distanceofinstantaneouscentrefromrearaxleaxis.

w mm.C_2=

f 452.80

= mm.

F

r o n t

tra c k w idth

.

From equation 3and4

Tofindδ_{of} =outerangleof fronttire.

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

$\delta_{of}=19.70^0$

Tofindδ_{ir}=innerangleofreartire.

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

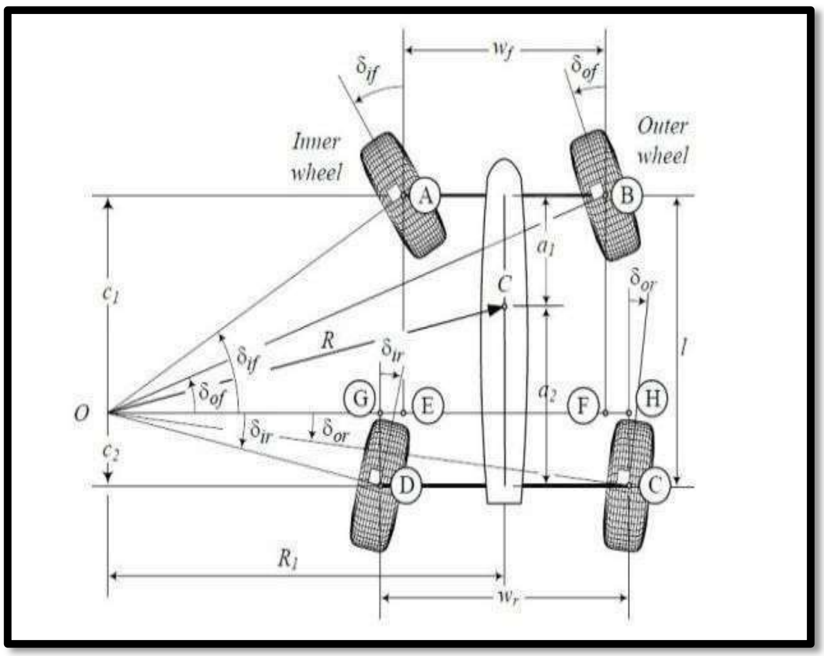
$\delta_{ir}=7.164^0$

C

1
=
1
7
2
2
. 1
9

Tofindδ_{if}=outerangleof reartire.

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



δ_{or}= 5.386^0

Figure35:Steeringanglespositionofinstantaneouscentreforturningradius4.4m

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

B. CALCULATIONOFTURNINGRADIUS

TOFINDSTEERINGRADIUS,R

$R^2=a^2+L^2\cot^2\delta$ ....(8)

Where 2

δ=Total steeringangleof thevehicle.

TOFINDδ

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

Where δ_i= total inner angle of the vehicle. δ_o=totalouterangleofthevehicle.

$\cot\delta$=1.032.

Fromequation8 R = 2596 mm.

calculation for C_1 and C_2 from equation 3 and 4 considering turning radius as 2596 mm. C_1 = 780.82 mm.

C_2=1394.17mm.

ConsideringC_1 and C_2as Distance of instantaneous centre from front axle axis and rear axle.

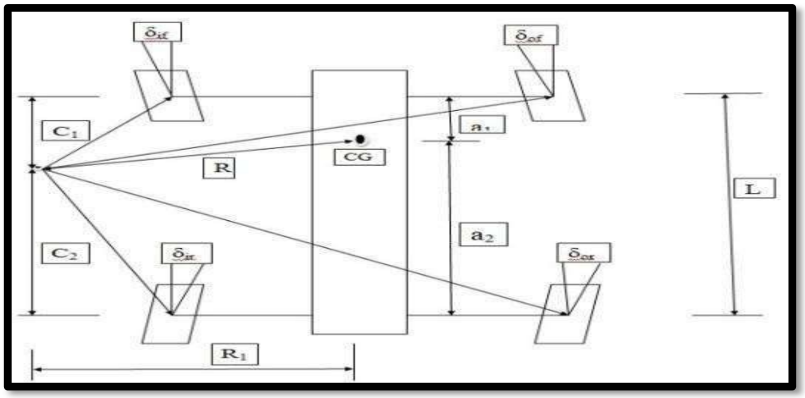


Figure36:Steeringanglesandpositionofinstantaneouscentreforturningradius2.59m

From Figure 28 and 29 we can see that there is a change in instantaneous center as thereischangeinturningradius.ThevaluesofC_1andC_2changesgradually,in figure 3 the value of$C_1$is greater and the value of $C_2$is lesser but in Fig as theturning 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 Ischangeinturningradiusfrom4.4mto2.59m.
Themodelisdesignedconsideringthesamewheelbaseandtrackwidth.Themodel isdesignedusingthesoftwareCATIAV5.

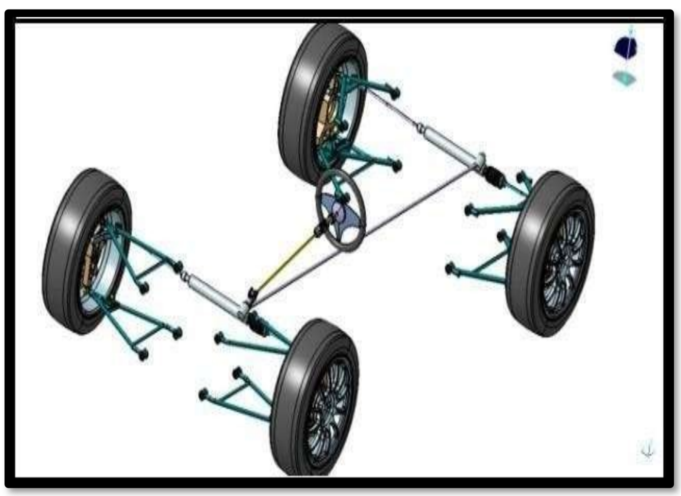


Figure37:DesignedCATIAmodel

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 forsuspensionand onlyone degree offreedomisappliedfor thesuspensionmotion,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 thebevelgearofsteering columnrotates inoppositedirection, so withrespect to the second bevel gear attached to the intermediate shaft.
The shaft rotates in the direction of the second bevelgear. 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.

C. FINALMODELCREATINGJOINTS:

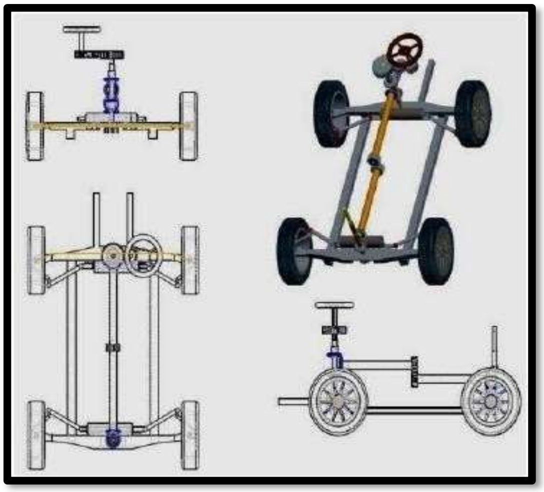


Figure38:Finalmodelaftercreatingthejoints

The final model after creating all the joints with respect to all parts. The joint given forfrontsteeringisreplicatedat the rear steering, there is bevelgearjoint provided between steering column and intermediate shaft.
This intermediateshaft 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.

Table8.1Jointsconnectedtotheparts

PART	PART	JOINT
Steeringwheel	Rackbody	Revolution
Steeringwheel	Steeringcolumn1	Hooke
Steeringcolumn1	Steeringcolumn2	Hooke
Steeringcolumn2	Rackbody	Cylindrical
Rack	Tierod	Translation
Tierod	Balljoint	Spherical
Balljoint	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) systemcar. So, this project is based on how to prove that the 4WS is better than 2WS in terms of turning radius

D. STIMULATIONOFTHREEMODESTEERING:

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

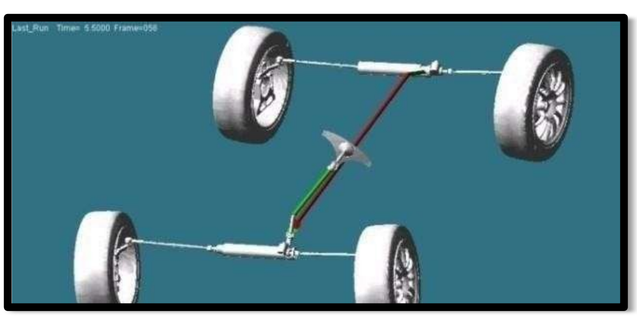


Figure39:Simulationofthreemodesteering

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 steeringis proved from the simulation.

E. DESIGN OFFRAME:

For building of prototype model, the designed model is considered along with thata 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,thesupportstructureforsteeringcolumnandrackbodyisweldedtotheframe.

The rear steering column is attached with the intermediate shaft also rotates as per the shaftsuch that the rear wheelsattached to the rear steering column rotates as perthe rear steering column, so the rear wheels rotates in opposite direction to the driver inputto thesteeringwheel.We conclude that allthefourwheels areturning at an angle, the front wheels turn as per the steering wheel turns and the rear wheels turn oppositeto the front wheels

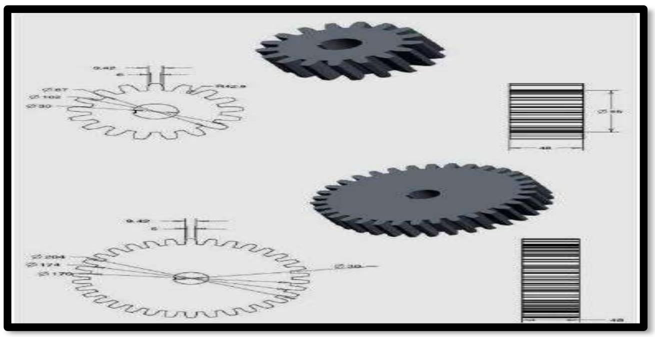


Figure40:SPURGEAR

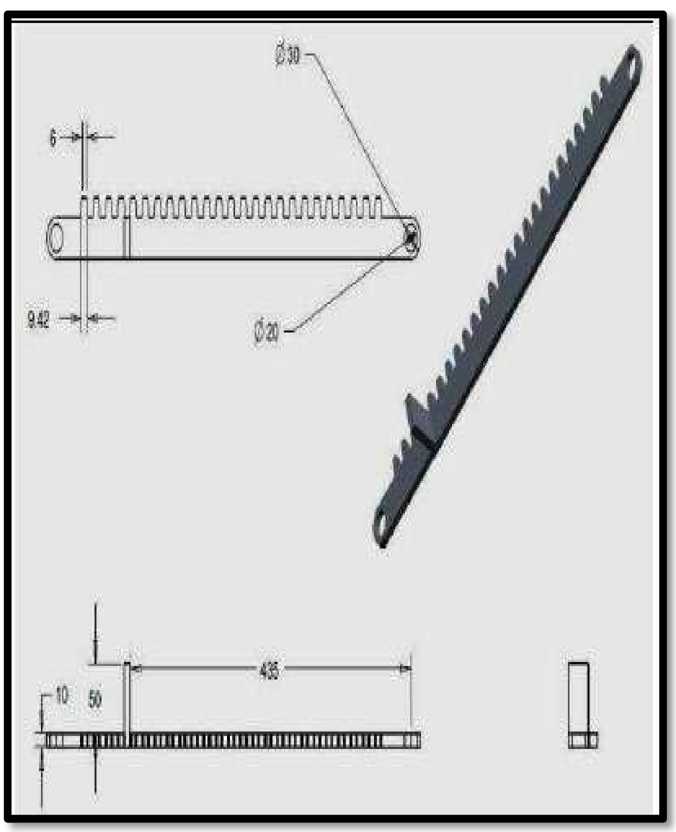


Figure41:RACK

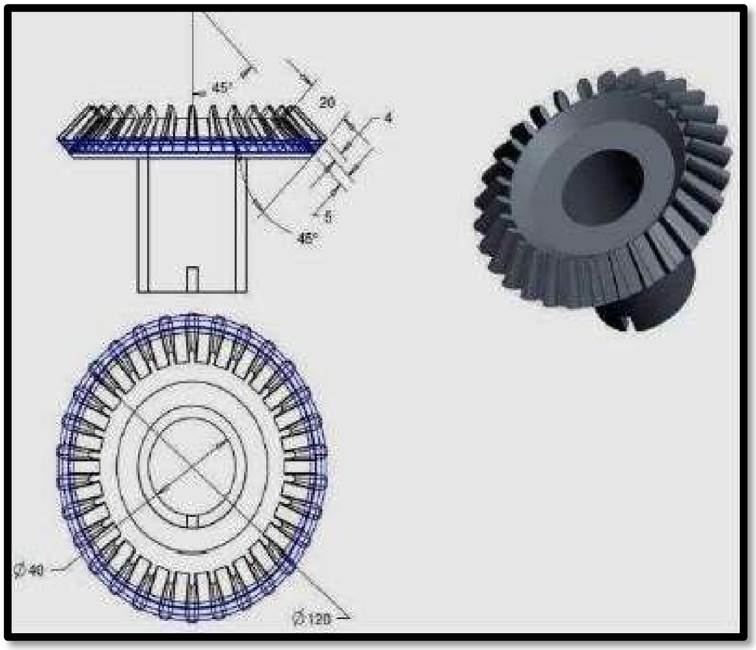


Figure42:BEVELGEAR

Figure43:Gearmeshing

F. FACTORSDETERMININGMATERIALS:

Thevariousfactorswhichdeterminethechoiceofmaterialarediscussedbelow.

1) Properties:

Thematerialselectedmustpossessthenecessarypropertiesforthe 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 decisivelyaffect their selection

- Physical
- Mechanical

From manufacturing point of view Chemical. The various physicalproperties 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,

- Castability
- Weldability
- Surfaceproperties
- Shrinkage

2) MANUFACTURINGCASE:

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

3) QUALITYREQUIRED:

Thisgenerallyaffectsthemanufacturingprocessandultimatelythematerial.Forexample,itwouldneverbedesirabletogocastingofalessnumber of components, which can be fabricated much more economically by welding or hand forging the steel.

4) AVALIBILITYOFMATERIAL:

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 substituteforthematerialdesigne.Thedeliveryofmaterialsandthedeliverydate of product should also be kept in mind.

5) SPACECONSIDERATION:

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

6) COST:

As in any other problem,in selection of material the cost ofmaterial playsan important part and should not be ignored.
Sometimes factors like scrap utilization, appearance, and non-maintenanceof the designed part are involved in the selection of proper materals.

VI. RESULTS AND DISCUSSION

A. CALCULATIONS:

1) NORMALMODE:

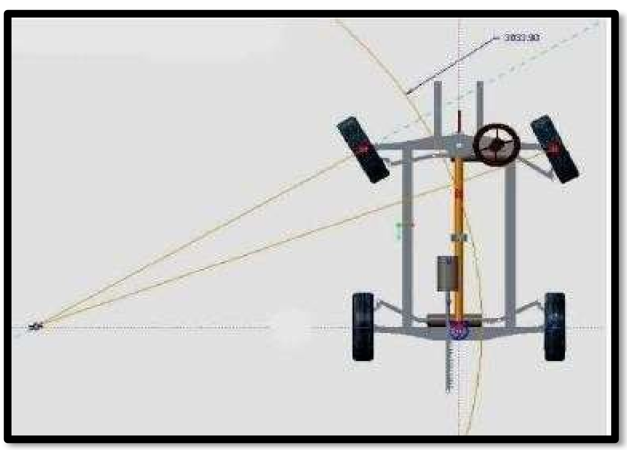


Figure44:NormalMode

Gravitationalacceleration(G)=
9.81m/s.GrossWeight (m)= 1350 kg.
Weightofvehicle(W)=m *g

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=13243.5NRadiusofWheel(rW)
=0.3556m.
Radiusofcurvature(R)
= 3 m. Width of Track(x) = 1.295 m. WheelBase(b)
=1.295m.
DistanceofC.G.verticallyabovetheroadsurface(h)=
0.55 m. Distance ofC.G. horizontally fromrear wheel axle (l)= 0.963 m. Linear velocity (V) = 26 Km/hr. Mass moment of inertia of wheel (I_W) =0.8 Nm
Massmomentofinertiaof rotatingpartsofengine(IE)
=13.5 Nm2. Angular velocityof wheels or velocity of spin=20.8902 rad/s .
Gearratio(G)=4
Angular velocity of rotating parts of engine (w)=83.561 rad/s. Velocity of precession (wP)
=2.4761rad/s.
Reactiononfrontwheelsduetoweight
=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.
Totalreactiononrearwheels(FR)=RiR-(PiR+QiR)=122.556N.

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

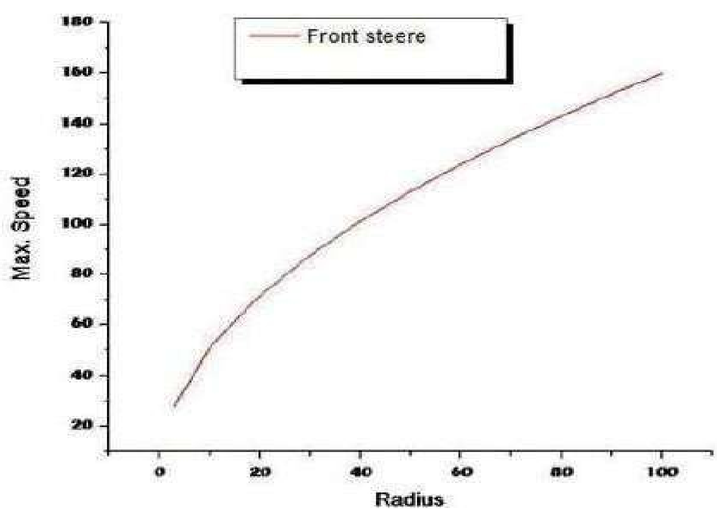

Figure45:GraphofRadiusvsMaxspeed

2) 2ND MODEOF

STEERING Gravitational acceleration(G)= 9.81 m/s. Gross Weight (m) = 1350 kg.
Weightofvehicle(W)=m*g
=13243.5NRadiusofWheel(rW)
=0.3556m.
Radiusofcurvature(R)= 1.7868 m. Width of Track(x) = 1.295 m.
WheelBase(b)=1.295m.
DistanceofC.G.verticallyabovetheroadsurface(h)=
0.55 m. Distance ofC.G. horizontally fromrear wheel axle(l)=0.963m.Linearvelocity(V)=16m/s. Mass moment of inertia of wheel (IW)= =0.8 Nm2
Mass moment of inertia ofrotating parts ofengine (IE) =13.5 Nm2. Angular velocity of wheels or velocity of spin (wW) =12.85554rad/s.Gearratio(G)=4
Angularvelocityofrotatingpartsof engine(we)==51.42214 rad/s. Velocity of precession (wP) =V/R =2.558444 rad/s Reaction on front wheels due to weight (Rif=ROF)=4924.128N. Reaction on rear wheels due to weight(RiR=RoR)=1697.622 N. Reaction at front wheels due to centrifugalforce(PiF=PoF)=4183.322 N.
Reaction at rear wheels due to centrifugal force(PiR=PoR)=1442.225 N. Reaction at front wheels due to gyroscopic effect(QiF=QoF)=141.8757 N. Reaction at rear wheels due to gyroscopic effect(QiR=QoR)=141.8757 N. Total reactionon front wheels(FF)=Rif-(PiF+QIf)=598.9295N
Totalreactiononrearwheels(FR)=RiR-(PiR+QiR)=113.5213N

NormalSteer Mode: Radius ofcurvature(R) = 3 m. Cross Steer Mode: Radius of curvature(R)=1.7868 m.
%Reduction=$^{3-1.7868}*100$=40.44%3

TABLE11.2TABULATION

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

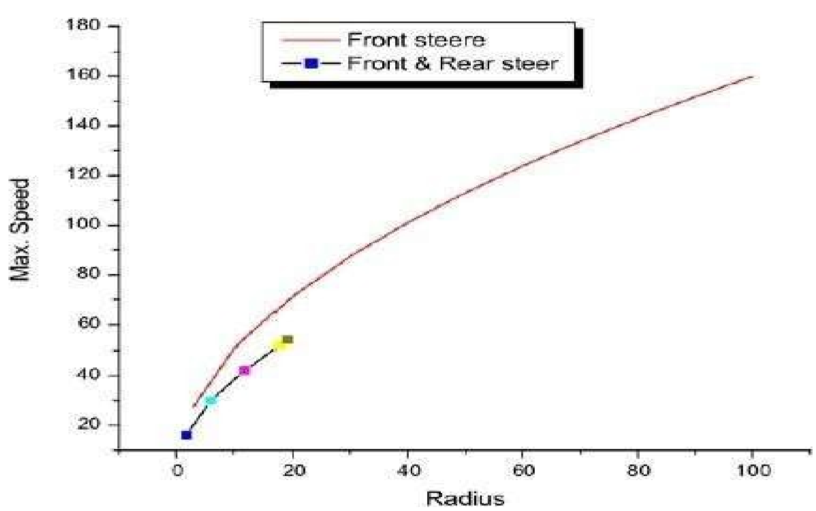

Figure46:GraphofRadiusvsMaxspeed

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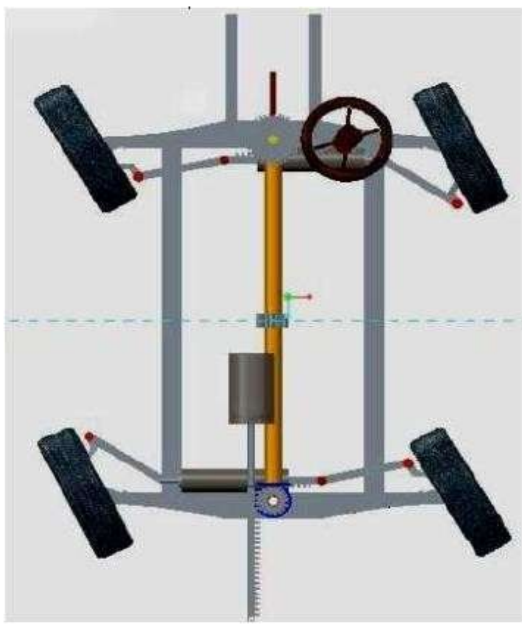
3) CRABMODE:

Gravitationalacceleration(G)=
9.81m/s.GrossWeight (m)= 1350 kg./
Weightofvehicle(W)=m*g
=13243.5NRadiusofWheel(rW)
=0.3556m.
WidthofTrack(x)=
1.295m.WheelBase
(b)=1.295m
Distance ofC.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.
Massmomentofinertiaofwheel(IW)
=0.8 Nm^2 Mass moment of inertia of rotating parts ofengine (IE) =13.5Nm2.
Angularvelocityofwheelsorvelocityofspin (Ww)=76.324 rad/s Gear ratio (G) =4 Angular velocity of rotating parts of engine (wE)=305.3189rad/s Cw =244.2551824 Nm. Ce= 4121.806203 Nm.



. C
=4366.061385
Nm.
W/2 = 6621.75N.
P/2 = C/2x = 1685.737987 N. R1=3238.857488 N. R2=11.41653844 N. R3=6610.333462N.
R4=6610.333462N.

Table11.3Comparisonfor two wheel steerandfourwheel steer

Turning radius	Fourwheelsteer	Two wheelsteer
By calculation	2.59m	4.4m
By experiment	2.85m	5.75m

4) *Advantagesofthreemodesofsteering*
- Easymaintenance.
- Modechangeiseasy.
- Implementationiseasy.
- Usedforeasyparkinginfourwheelers.
- Itisapplicableforall fourwheeledvehicles.

5) *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.

VII.CONCLUSION

Aninnovativefeatureofthissteeringlinkagedesignisitsabilitytodrive all four (or two) wheels using a single steering actuator. Its successful implementationwillallowforthedevelopmentofafour-wheel,steeredpower base with maximum maneuverability, uncompromised static stability, front- andrear-wheel tracking, and optimum obstacle climbing capability.

Thusthefour-wheelsteeringsystemhasgotcorneringcapability, steering response, straight-line stability, lane changing and low-speed maneuverability. Even though it is advantageous over the conventional two-wheel steeringsystem,4WSis complexandexpensive.Currentlythecostofavehicle with four wheel steering is more than that for a vehicle with the conventional two wheelsteering.Fourwheelsteeringisgrowinginpopularityanditislikelyto 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 impressing task in the field of automobile industries. It is very usefully for driver while driving the vehicle. This projecthasalsoreducedthecostinvolvedintheconcern.Projecthasbeen designed to perform the entire requirement task which has also been provided.

VIII. ACKNOWLEDGEMENT

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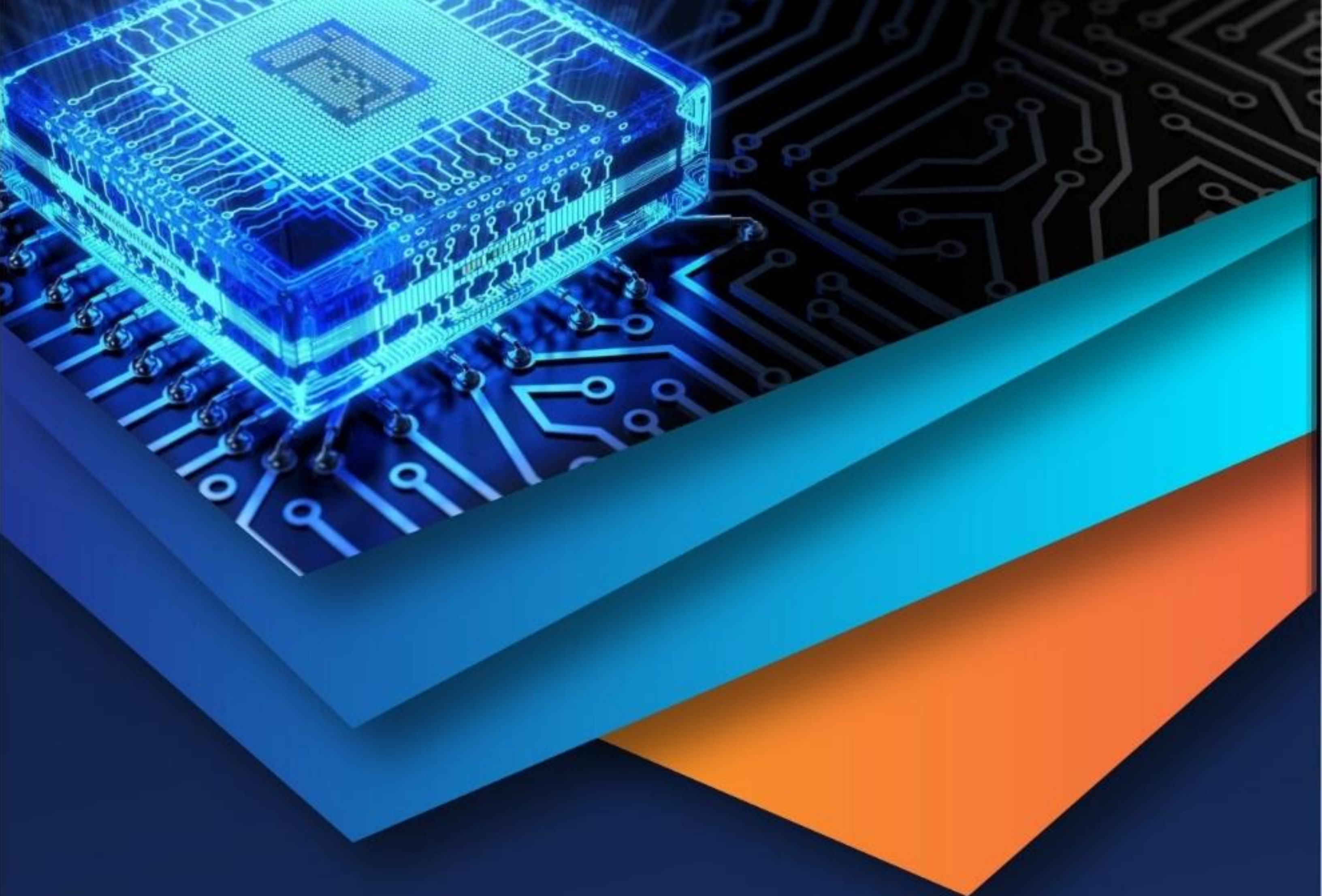

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