

Design and Fabrication of Four-Wheel Steering System for Efficient Transportation Systems

P. Suresh Kumar, Swapnil Joshi, N. Prasanthi Kumari



Abstract: Automobile industry is one of the most important segment for a country's growth. India facing its own challenges due to its huge and varied transport sector. These challenges may overwhelmed by using energy efficient advancements with the customer focused approach. The driver always driving the automobile with sophisticated technologies and should feel very comfortable. Automobile moving higher than the cruising speeds stability of the vehicle is the key factor. In four-wheel navigation system the tail wheels turning opposite to the forward-facing wheels while vehicle moves at high speeds instability chances are more. To avoid this instability rear wheels follows the same track of the forward-facing wheels while tuning of the all-wheel steering system. This paper focusing light on to the difficulty faced when all wheel steering system taking a turn in a very confined space. By switching from two wheel steering to four wheel steering owing to this the driver on the way to make turns in small radius. It also laidback for parallel parking and maneuvering the vehicle quite with no trouble on highways. In command to succeed this, a mechanism established with the two bevel gears and intermediary shaft, which transfer 100% rotating force as well turns tail wheels in out of period. The spiraling radius of the automobile with two steering wheel system is 4400 mm after switching to four-wheel steering system radius is 2596mm only. Hence, radius reduced to 1804 mm.

Index Terms: steering system, trundle, navigating, bevel gears, torque and shaft.

I. INTRODUCTION

Recent trends show that researchers have moved toward making vehicle more comfortable and secure focusing more on ergonomics and safety. One of the most ignored area remains the steering system, which, control maneuverability of the vehicle. [1] This project focuses on making steering more optimal by using four wheel steering. This task goes for building up a counter stage wheel guiding in which back wheels turn inverse way to that of front wheels. This mode can be utilized to move the vehicle through blocked city everywhere improved cornering is essential and constricted lanes with short whirling span, this may be utilized as, appeared diagram given underneath. At High Speeds, the automobile may insecurity the rear wheels from end to end a point reverse to forward-facing wheels and is therefore unacceptable. Consequently the back wheels are turned a alike way of forward-facing wheels in all-wheel controlling

structures. [2] This task goes for building up a counter stage wheel guiding in which back wheels turn inverse way to that of front wheels. This mode can be utilized to move the vehicle through blocked metropolitan cities and towns where improved pin down is necessary and close fitting lanes by little whirling span this may be utilized as appeared shown figure given underneath. Consequently here stands a prerequisite to system that outcome in little whirling sweep then this one very well may accomplished by executing all wheel controlling. [4] All steering control exists technique created at automobile car manufacturing aimed at t successful whirling of the automobile in addition towards build the system. Thus run of the mill front wheel controlling framework the back wheels don't turn toward the bend and therefore check taking place productivity of the guiding. In all steering roll directing the rare steering rolls go by the forward-facing rolls in this manner expanding the proficiency matters to automobile. Heading of controlling back rolls with respect toward the forward-facing rolls relies upon working conditions. [5] In a common front wheel controlling framework the back wheels don't turn toward the bend and accordingly check on the productivity of the guiding. Regularly this framework isn't been the favored decision because of multifaceted nature of ordinary mechanical four wheel guiding frameworks. Notwithstanding, a couple of vehicles identical Honda Prelude, Nissan Skyline GT-R partake remained accessible with all steering roll directing frameworks, wherever the back rolls go with verge headed for help the forward-facing rolls here controlling. Notwithstanding, frameworks ensured the back rolls guided means of just two or three grades, in place of this primary point be there towards help the forward-facing rolls instead of cow without anyone else. [6] To comprehend the upsides of four-wheel guiding, it well informed to audit the elements of regular controlling moves with a customary front - directed vehicle. The tires are liable to the powers of grasp, energy, and controlling info as soon as manufacture development former more straightforward-onward motivating. In powers contend through one another for the period of directing moves. Using forward-facing-guided automobile backside continually attempting gearing up the speed to guide modifications to forward-facing rolls. Hence makes automobile influence. As a typical piece of working a vehicle, the driver figures out how to change in accordance with these powers without thinking about them. As soon as whirling, the chauffeur is placing keen on movement a complex arrangement powers. Everyone must adjusted opposite the travelers. The wheels exposed for street grasp, slide edge. Grasp clamps vehicle's rolls on street momentum propels the vehicle vertically stand. Controlling info makes the front wheels turn.

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The vehicle immediately opposes the turning movement, causing a tire slip point to shape. [7] All rolls controlling technique created in car manufacturing aimed at the successful whirling automobile, build mobility. In common forward facing rolls guiding framework back trundles does not go toward bend and along these lines check taking place productivity then controlling. All steering rolls directing rare trundles go through forward-facing rolls along these lines expanding the effectiveness with automobiles. The heading controlling back trundles in respect of forward-facing trundles relies upon working environments. For less quickness trundle development articulated, with the goal that back wheels are controlled the other way to that of front wheels. [8] In that controlling framework, the every one of the four wheels are to be directed by the cow perform to drive towards left or right. All-trundle guiding, 4WS, likewise entitled back trundle directing or else all-trundle controlling, gives way for effectively guide the back trundles in the course of whirling moves. This ought not stay exist mistaken for all-trundle motivation vogueish all trundles of a automobiles are controlled. Then develops taking care of as well as enables the automobiles to create more tightly seizures. Creation manufactured vehicles be apt to underneath cow otherwise small number examples in excess of cow. On the off chance that a vehicle could consequently make up for an under cow/over cow issue, the driver would appreciate about impartial guiding under changing conditions. [9] The heading of directing the back wheels with respect to the forward-facing trundles relies upon working state of affairs. On little-quickness trundle development is articulated, with the goal that back wheels are controlled the other way to that of front wheels. This additionally rearranges the situating of the vehicle in circumstances, for example, leaving in a kept space. Since the back wheels are made to pursue the way out and about engaged by the forward-facing trundles, rare of a 4WS vehicle doesn't go vogueish typical manner. In this way the danger of hitting an obstruction is enormously diminished. [10] At rapid, when controlling modifications are unobtrusive, the front haggles wheels turn a similar way (Jack Erjavee, 2009). Subsequently, the automobile travels crab-like way instead of in a bended way.

These activities profitable to the automobile however switching to another lane on a rapid street. The disposal of the radial impact, result decrease frame troll, trapping power on wear out, progresses the soundness for vehicle with the goal that control ends up simpler and more secure. For 4WS framework, governor of drive point on forward-facing then back trundles are generally basic. [11] The four wheels have completely free controlling and need to turn a flighty way to guarantee that the vehicle pivots alone hub. Such a framework requires exact count from a servo engine with continuous input to verify that each of the three directing modes work superbly. The main serious issue presented by this design is that an ordinary rack-and-pinion guiding with pitman support is not giving good results and is not fitting to particularly this approach, then 2 forward-facing trundles exist controlled vogueish inverse ways. Hurricane automobile-jeep is accompanied the all wheels Navigating Organism (Thomas Birch, 1987). Navigate cable structure mechanisms might effort good, some times, from the time when open regulator be able to achieve. [12] Generally public places forward-facing trundle regulatory structure rare trundles do not turn toward the bend and in this way

check for proficiency goes directing. All trundle controlling back trundles move on forward-facing trundles along these lines expanding the productivity of automobile. Bearing can directing back trundles with respect headed for forward-facing trundles relies upon the working environments. [13] Little quickness trundle development articulated, with the goal that back wheels are controlled the other way to that of front wheels. At fast, when guiding modifications are unpretentious, the front haggles back wheels turn a similar way decrease whirling range of automobile exists effective vogueish leaving, little quickness confronting, rapid path variation. [14] Metropolitan driving circumstances automobile through upper trundle base, pathway distance across surface issues of whirling with space is bound, a similar issue is looked vogueish little quickness pin down. Normally clients take automobile developed trundle base, pathway measurement own solace, facade all issues, conquer issue an idea of all trundle guiding was embraced to automobile. [15] In that directing framework, the every one of the four wheels are to be controlled by the cow perform to drive towards left or right. All-trundle guiding, 4WS, additionally named back trundle directing and all-trundle controlling, gives way effectively direct the rare trundles in between whirling moves. Ought not to mistaken for all-trundle get-up-and-go for every one the all trundles of automobiles fueled. Then develops taking care of and enables automobile to create more tightly rounds. Creation constructed vehicles be apt to underneath cow, a small number of occasions, above cow. In the event that a vehicle could consequently make up for an under cow/over cow issue, the driver would appreciate almost nonpartisan guiding under shifting conditions. [16] In most dynamic all trundle controlling framework, the back wheels are guided by a PC and actuators, the back wheels by large can't turn similar to the front wheels. A few frameworks including Delphi's Quadra steer and the framework in Honda's Prelude line enable the back wheels to be controlled the other way as the front wheels during low speeds. This enables the vehicle to turn in a fundamentally littler span now and then basic for enormous tucks or tractors and vehicles with trailers. [17] The four wheel guiding is utilized to limit the turning range of the vehicle when contrasted with the conventional controlling instrument. The customary directing system includes the utilization of Ackerman controlling instrument. Utilizing these controlling frameworks the principle disservice is that it's more. For disposing of this, it is proposed to utilize four wheel guiding framework. [18] Flexibility of the turning range of wheel can be accomplished uniquely at low speed. The front hagle back wheel turn a similar way at fast as it encourages path evolving. A front wheel does the majority of the controlling while the back wheel's turning is restricted to half during a contrary heading. [19] Two wheel directing framework can control the vehicle however it isn't sufficient to drive the vehicle in little, thin space or in rush hour gridlock. So this task depends on this idea and has four wheels controlling to control the vehicle in practically all condition. From past research, we were seeing that four wheel controlling framework isn't totally powerful at a fast on the grounds that at rapid vehicle can't take a turn utilizing there four haggles utilizing then there will be an opportunity of slipping.

We will improve guiding by consolidating 2WS frameworks. [20] As the four-wheel guiding (4WS) framework has extraordinary possibilities and numerous specialists' consideration was pulled in to this system and dynamic research was made. Therefore, traveler vehicles outfitted with 4WS frameworks put available a couple of years prior. This report attempts to recognize the basic components of the 4WS innovation as far as vehicle dynamics and control systems. In view of the discoveries of this examination, the report gives a layout and point of view of the exploration regions included. [21] To comprehend the upsides of four-wheel controlling, it is astute to audit the elements of run of the mill guiding moves with a regular front - directed vehicle. The tires are liable to the powers of hold, energy, and guiding info as soon as manufacture a development further straight-ahead driving. Hence, powers contend on one another din between guiding moves. On a forward-facing-controlled automobile, backside be present continually attempting be make active for lost time to the directional modifications of the forward-facing trundles. Therefore, makes the automobile influence. As an ordinary piece of working a vehicle, the driver figures out how to change in accordance with these powers without contemplating them. [22] As per earlier said all-trundle guiding of automobile pays less motorist contribution in place of some controlling move suppose each of the all trundles directing automobile. Same manner on 2-trundle steer automobiles, tire grasp clamps all trundles mobile. In any case, when the driver turns the wheel somewhat, every one of the all trundles respond for controlling information, make happen slide edges shape for all trundles. The whole vehicle moves in a single bearing instead of the back half endeavoring to get up to speed to the front. Likewise low influence while trundles gone posterior for conventional-forward locus. Automobile reacts all the excessive rapidly for controlling information since back wheel slack is dispensed with. [23] four-wheel controlling, 4WS, additionally called back wheel directing or four-trundle regulatory, results to drive efficiently for control rare trundles during rounding travels. Framework that creates habitat for all every one of the all trundles guide automobile. The controlling edge is normally restricted to 2° or 3° . Turning the back wheels the other way to the front at moderate paces can permit quicker moving and an a lot more tightly turning span. Turning the back wheels a similar way as those at the front at rapid permits abrupt path changes with a lot more noteworthy steadiness. Turning the back wheels a similar way as the front when stopping makes parallel stopping a lot simpler. [24] Four wheel controlling generally modern innovation progresses mobility in vehicles, automobiles and clips. It ought not be mistaken for four wheels drive in which each of the four wheels of a vehicle are fueled. In four-wheel controlling frameworks, rare wheels be able to round port and opposite to left. To keep driving controls as basic as would be prudent, a PC is utilized to control the back wheels. [25] The "Dynamic 4 trundle Navigating" altered type of AWS (4 - Trundle Piloting). In this, commitment, separation on all trundles guiding should be possible according to the driver ease. This gives the advantages of both two - haggle wheel steer. In this way, may utilized forward-facing trundle navigate lengthy conventional tracks may be utilized 4 - trundle navigate if severe - local turns required.

Modern new peer group energetic navigating methods make a distinction a necessity of piloting back trundles aimed on goal guiding constancy as of a necessity navigating to tail trundles purpose of confronting at little quickness.

II. DESIRES AIMED AT CORRECT RISING AND FALLING

Whereas handling turn, stating a seamless rising and falling movement can fulfilled if everything the 4 - trundle knives if anticipated for single point made immediate centers.

III. SLOW AND EXTRAORDINARY SPEEDINESS APPROACHES

On deliberate speed, back trundles turn bearing reverse of forward-facing trundles. Present technique cast-off in place of investigating from end to end inclining zones, in blocked metropolitan cities and town everyplace improved confronting prerequisite for U - direction turn, heavy traffic tight junctions little whirling round, this decreased. Great Speediness, whirling back trundles over and done with edge contradictory forward-facing trundles may provoke automobile shakiness, as such inadmissible. From this time forward, the back wheels are turned a comparable method for front wheels in four-wheel controlling systems

IV. PARALLEL CAR PARKS

Zero cow would altogether be able to encourage the halting methodology, this incredibly dumpy whirling impression. Its demonstrated as a result similar halting circumstance, these standard vogueish remote nations, very pertinent in the direction of urban regions. Vehicle needs towards leave it in the middle of 2-distinctive automobiles left taking place organization way. Move requires 3-approach improvement automobile, along these lines overpowering coordinating information sources. Furthermore, to adequately leave the vehicle without obtaining any mischief, at any rate many events stretch of vehicle essential open intended leaving 2-wheel coordinated vehicle. By way comprehended indisputably, vehicle necessitates essentially a comparable stretch by way of aforementioned leave predicament. 360 approach ensures not necessitate directing information sources, motorist basically leave automobile devoid of reaching controlling trundle. Needs on the road to look after provide control, power-assisted brake feedbacks, electronic in current automobiles. Along these lines, organism be able to uniform incite automobiles be able to motivation, stop without any other person's info.

V. RAPID LANE ALTERING

Another driving move that as often as possible winds up lumbering and even hazardous is moving to another lane at genuinely high speeds. In spite of the fact that is fewer guiding serious, make sure of not necessitate ton fixation commencing motorist needs pass judgment taking place and automobiles overdue motorist. The way crab approach rearrange activity.

V. METHODOLOGY

Procedure:

Torque from steering wheel is transferred to pinion which in turn provide translatory motion to front rack. There is switching box, operated through lever which used to switch between high speed maneuver to low speed maneuver ie four wheel steering to two wheel steering as per requirement.

Two-wheel steering

Exactly when a driver going at expressway paces turns the wheel of a normal, two-wheel guiding vehicle, the front tires rapidly begin to pivot and the vehicle's forward vitality delivers an extraordinary sideways or cornering power at the front center point. The back wheels, regardless, need to hold up until the vehicle has truly started its turn before they begin to create a looking at power at the back rotate. That is the reason a vehicle with two-wheel controlling fishtails during way changes; the back end is endeavoring to get up to speed to the front. In ludicrous cases, or under slippery conditions, the back of the vehicle may fishtail crazy.

Four-wheel steering

All-trundle navigating, 4 -WS, likewise known as back trundle controlling or wholly-trundle directing, gives way effectively guide back trundles for the period of whirling moves. Have to mistake for all-trundle drive in every one the all trundles of automobile controlled. Progresses dealing with enables automobile to create more tightly rounds. Generation assembled autos be apt to further down cow, in few occurrences, above cow. On the off chance that a vehicle could naturally make up for an under cow/over cow issue, the driver would appreciate about impartial guiding under fluctuating conditions. 4WS is a genuine exertion with respect to car configuration architects to give close unbiased controlling. Forward-facing trundles organize a large portion on guiding. Rare trundle whirling commonly constrained in the direction of quasi for the period contrary bearing round. At the point while two forward-facing and back trundles navigate to a similar course, it said towards be in phase, it delivers sort of indirect development on vehicle stumpy swiftness. At point when the forward-facing, back trundles guided inverse way, this is called hostile to stage, counter-stage or inverse stage and it delivers a more keen, more tightly turn.

Switching mechanism

Switching box contains two rack and pinion assembly placed orthogonally to each other. Torque is transferred from steering wheel to pinion which in turn provides the linear motion to rack. Another rack which is welded on this rack with its teeth orthogonally to former moves with it. Pinion is connected to a shaft which slides inside another circular shaft with help of lever.

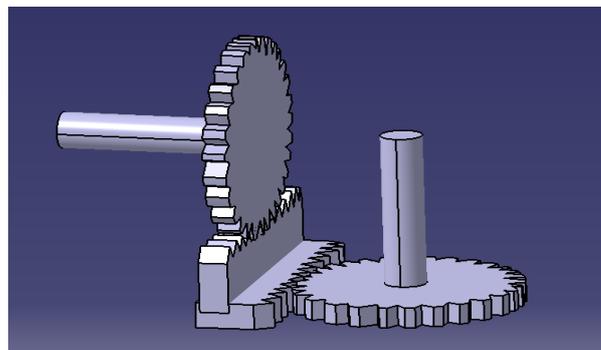


Fig 1: Front rack and pinion assembly in switching box
Vehicle can be operated in two phases bestowing towards constraint a) All trundle navigating: Steering wheel is used to turn both front and rear wheels b) Two wheel steering: Steering wheel is used to turn only the front wheels.

PHASE 1: Low speed maneuvers



Fig 2: Low speed maneuver linkage position

At low speed while maneuvering through small turns four wheel steering can be used to have reduction in turning radius. In this mode the pinion takes the torque from steering wheel and transfers it to front rack. Pinion 2 can slide inside a circular shaft with the help of lever to bring it in contact with rack teeth. This pinion transfers the torque to rear rack and pinion assembly through circular shaft, which turns the rear wheels in contradictory track of forward-facing wheel.

PHASE2: Great quickness maneuvers



Fig 3: Great quickness maneuver linkage position

VI. CALCULATIONS

Side view calculations

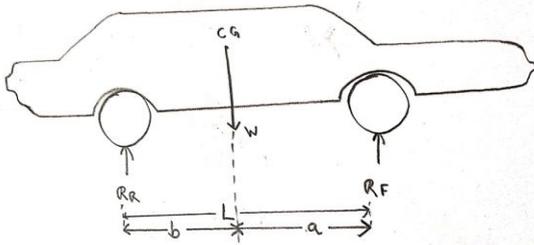


Fig 4: Side view of a vehicle

Wheel base (L)= 1301.75 mm
 b=Measurement between back axle starting CG
 a= Measurement between forward-facing axle starting CG
 W=Weight (car) = 40 kg
 $R_r = 127.53 \text{ N}$
 $R_f = 264.87 \text{ N}$

Where
 R_r = Reaction force on rear axle.
 R_f =Reaction on front axle.
 So, $L = a + b$ (1)

Sum of all forces about Y axis=0
 $\sum F_y = 0$
 $W = R_r + R_f$ (2)

$\sum M_r = 0$ (M= Total Moment about rear wheel)
 $R_f \times L = W \times b$
 $b = R_f \times L / W$ (from equation 1 & 2)

So, $b = 878.68 \text{ mm}$
 $a = 423.07 \text{ mm}$

Calculations of front view

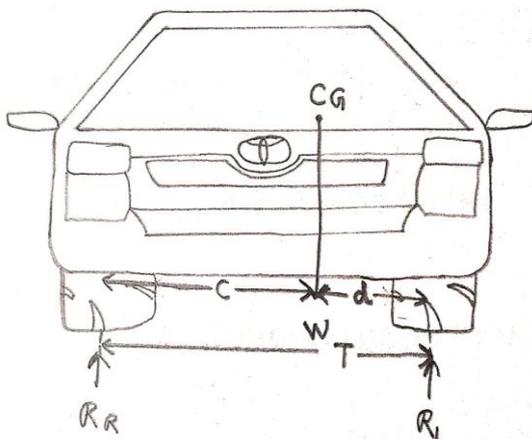


Fig 5: Front view of a vehicle

Side location of CG
 Track width (T) = 652.78mm
 c=Distance between center of gravity and right wheel
 d= Distance between centre of gravity and left wheel

Sum of all forces about Y axis
 $\sum F_y = 0$
 $W = R_r + R_l$

Where
 R_r = Reaction force on right wheel
 R_l = Reaction force on left wheel

$\sum M_l = 0$ (Total moment about left wheel)
 $W \times c = R_r \times T$
 So, $c = R_r \times T / W$

So, $c = d = 326.39 \text{ mm}$

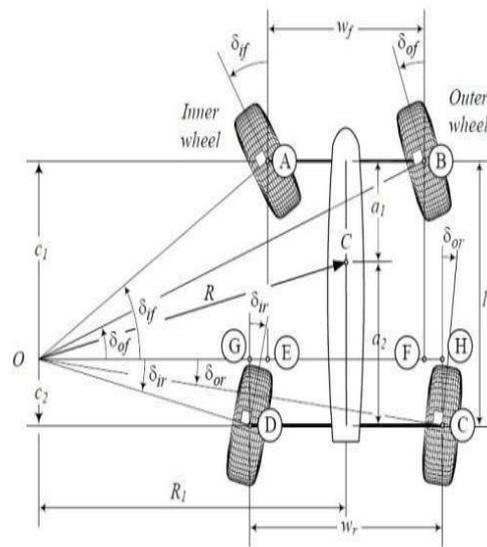


Fig 6: Navigating directions to instant focus on whirling range 4.28m.

Inner lock angles for front tyre 24.1.
 Navigating angles for whirling limit - 4.28m.
 Standard automobile whirling limit - 4.28 m.
 As per standard data
 $R^2 = a^2 + R1^2$ (1)

Where
 R = Whirling limit.
 a^2 = Measurement of CG starting back axle.
 $R1$ = Measurement between on spot centre and axis of automobile.
 $TW_f = (W \times a2) / L$ (2)

W_f = Load on forward-facing axle.
 W = Total weight (Automobile)
 L = Trundle base.
 So from equation 2 and 1
 $a2 = 1105 \text{ mm}$.
 $R1 = 4002 \text{ mm}$.
 Navigating slants;
 Inner slant of forward-facing tyre, $\delta_{if} = 24.1$
 $\tan \delta_{if} = C1 / (R1 - w_f / 2)$ (3)

$C1 + C2 = L$ (4)
 Where



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C_1 = Measurement between instant centre and forward-facing hinge alignment.

C_2 = Measurement between instant centre and back hinge alignment.

W_f = Forward-facing trajectory width.

From equation 3 and 4

$$C_1 = 1522.19 \text{ mm.}$$

$$C_2 = 492.80 \text{ mm.}$$

δ_{of} = outer slant forward-facing tire.

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

$$\delta_{of} = 17.54$$

δ_{ir} = inner angle of rear tire.

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

$$\delta_{ir} = 6.83$$

δ_{or} = outer angle of rear tire.

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

$$\delta_{or} = 4.98$$

Steering angles are taken same for front and rear wheels. Trundle base, trajectory span are considered equivalent to standard automobile.

R (Whirling radii)

$$R^2 = a^2 + [(L^2) \times (\cot^2 \delta)] \dots \dots \dots (8)$$

δ = Full navigating angle.

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

δ_i = full interior angle.

δ_o = full exterior angle.

$$\cot \delta = 1.032.$$

From equation 8

$$R = 2395 \text{ mm.}$$

Now C_1 and C_2 (equa 3 and 4) is done with whirling radii 2596 mm.

$$C_1 = 760.82 \text{ mm.}$$

$$C_2 = 1194.17 \text{ mm.}$$

Let us verify that the steering follows Ackermann Mechanism

$$\cot \delta_{of} - \cot \delta_{if} = P/L$$

$$\cot 18.66 - \cot 25.6 = 0.874$$

$$z/L = 1133.65 / 1301.75 = 0.870$$

As LHS = RHS, so Ackermann mechanism is followed.

Here P is distance between pivot centres

VII. DESIGN

The design of 3D model is done using SOLIDWORKS software with proper dimensions.

All the linkages of the system are shown using line diagrams.

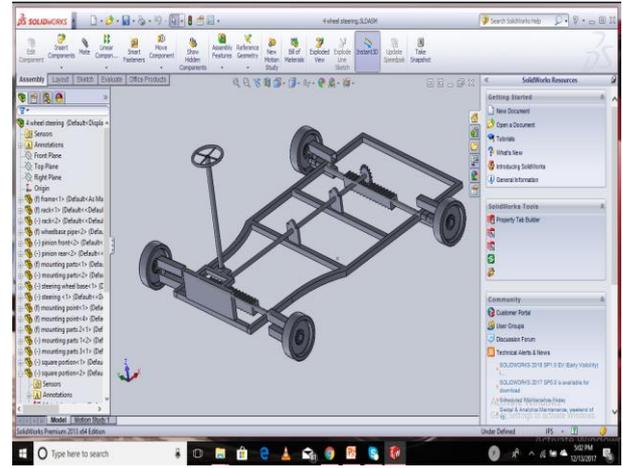


Fig 7: CAD model of the frame designed using SOLIDWORKS

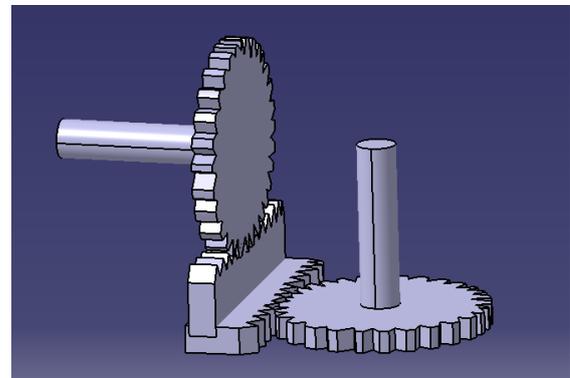


Fig 8 CAD model of the switching box linkage designed using CATIA V5

Design

The design of 3D model is done using SOLIDWORKS software with proper dimensions.

All the linkages of the system are shown using line diagrams.

VIII. CONCLUSIONS

From the experimental results and the theoretical results, conclude the following:

- Whirling range of all-trundle steering is less than the turning radius of two-wheel Steering reduced about 1804 mm.
- The inner angle of front tire is, $\delta_{if} = 24.1$, outer angle of front tire, $\delta_{of} = 17.54$.
- It is more advantageous to use four-wheel steering than two-wheel steering in situations where the space available for turning is less.
- Hence, the all-trundle navigating is more efficient than the two-wheel steering.
- For Parallel parking, four-wheel steering is more suitable compared with the two-wheel steering.
- Lanes be switched easily at lower speeds.

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