

DEVELOPMENT OF FOUR WHEEL STEERING SYSTEM FOR A CAR

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Abstract

Production cars are designed to understeer and rarely do they oversteer. If a car could automatically compensate for an understeer/oversteer problem, the driver would enjoy nearly neutral steering under varying operating conditions. Four-wheel steering is a serious effort on the part of automotive design engineers to provide near-neutral steering. Also in situations like low speed cornering, vehicle parking and driving in city conditions with heavy traffic in tight spaces, driving would be very difficult due to vehicle's larger wheelbase and track width. Hence there is a requirement of a mechanism which result in less turning radius and it can be achieved by implementing four wheel steering mechanism instead of regular two wheel steering.

In this project Maruti Suzuki 800 is considered as a benchmark vehicle. The main aim of this project is to turn the rear wheels out of phase to the front wheels. In order to achieve this, a mechanism which consists of two bevel gears and intermediate shaft which transmit 100% torque as well turns rear wheels in out of phase was developed. The mechanism was modelled using CATIA and the motion simulation was done using ADAMS. A physical prototype was realised.

The prototype was tested for its cornering ability through constant radius test and was found 50% reduction in turning radius and the vehicle was operated at low speed of 10 kmph.

Nomenclature

L	Wheelbase (mm)
R	Turning radius (mm)
a_2	Distance of CG from rear axle (mm)
δ_{if}	Inner angle of front tire (degree)
δ_{of}	Outer angle of front tire (degree)
δ_{ir}	Inner angle of rear tire (degree)
δ_{or}	Outer angle of rear tire (degree)
R_1	Distance between instantaneous centre and the axis of the vehicle (mm)
W_f	Load on front axle (kg)
W	Total weight of car (kg)
C_1	Distance of instantaneous centre from front axle axis (mm)
C_2	Distance of instantaneous centre from rear axle axis (mm)
w_f	Front track width (mm)
w_r	Rear track width (mm)
δ	Total steering angle of the vehicle (degree)
δ_i	Total inner angle of the vehicle (degree)
δ_o	Total outer angle of the vehicle (degree)

1. INTRODUCTION

Four wheel steering is a method developed in automobile industry for the effective turning of the vehicle and to increase the maneuverability. In a typical front wheel steering system the rear wheels do not turn in the direction of the curve and thus curb on the efficiency of the steering. In four wheel steering the rear wheels turn with the front wheels thus increasing the efficiency of the vehicle. The direction of steering the rear wheels relative to the front wheels depends on the operating conditions. At low speed wheel movement is pronounced, so that rear wheels are steered in the opposite direction to that of front wheels. At high speed, when steering adjustments are subtle, the front wheels and the rear wheels turn in the same direction.

By changing the direction of the rear wheels there is reduction in turning radius of the vehicle which is efficient in parking, low speed cornering and high speed lane change.

In city driving conditions the vehicle with higher wheelbase and track width face problems of turning as the space is confined, the same problem is faced in low speed cornering. Usually customers pick the vehicle with higher wheelbase and track width for their comfort and face these problems, so to overcome this problem a concept of four wheel steering can be adopted in the vehicle. Four wheel steering reduces the turning radius of the vehicle which is effective in confined space, in this project four wheel steering is adopted for the existing vehicle and turning radius is reduced without changing the dimension of the vehicle.

2. BACKGROUND THEORY

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

In a typical front wheel steering system the rear wheels do not turn in the direction of the curve and thus curb on the efficiency of the steering. Normally this system is not been the preferred choice due to complexity of conventional mechanical four wheel steering systems. However, a few cars like the Honda Prelude, Nissan Skyline GT-R have been available with four wheel steering systems, where the rear wheels turn by an angle to aid the front wheels in steering. However, these systems had the rear wheels steered by only 2 or 3 degrees, as their main aim was to assist the front wheels rather than steer by themselves.

With advances in technology, modern four wheel steering systems boast of fully electronic steer-by-wire systems, equal steer angles for front and rear wheels,

and sensors to monitor the vehicle dynamics and adjust the steer angles in real time. Although such a complex four wheel steering model has not been created for production purposes, a number of experimental concepts with some of these technologies have been built and tested successfully.

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

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

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

The idea behind four-wheel steering is that a vehicle requires less driver input for any steering maneuver if all four wheels are steering the vehicle. As with two-wheel-steer vehicles, tire grip holds the four wheels on the road. However, when the driver turns the wheel slightly, all four wheels react to the steering input, causing slip angles to form at all four wheels. The entire vehicle moves in one direction rather than the rear half attempting to catch up to the front. There is also less sway when the wheels are turned back to a straight-ahead position. The vehicle responds more quickly to steering input because rear wheel lag is eliminated.

The direction of steering the rear wheels relative to the front wheels depends on the operating conditions. At low speed wheel movement is pronounced, so that rear wheels are steered in the opposite direction to that of front wheels. This also simplifies the positioning of the car in situations such as parking in a confined space. Since the rear wheels are made to follow the path on the road taken by the front wheels, the rear of a four wheel

steering car does not turn in the normal way. Therefore the risk of hitting an obstacle is greatly reduced.

At high speed, when steering adjustments are subtle, the front wheels and the rear wheels turn in the same direction. As a result the vehicle moves in a crab like manner rather than in a curved path. This action is advantageous to the vehicle while changing lanes on a high speed road. The elimination of the centrifugal effect and in consequence the reduction of body roll and cornering force on the tire, improves the stability of the car so that control becomes easier and safer.

2.1 Application of four wheel steering

Parallel parking

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

As can be seen clearly the car requires just about the same length as itself to park in the spot. Also since the 360 degree mode does not require steering inputs the driver can virtually park the vehicle without even touching the steering wheel. All he has to do give throttle and brake inputs and even they can be automated in modern cars. Hence such a system can even lead to vehicles that can drive and park by themselves.

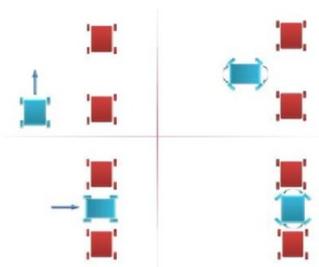


Fig. 1 Parallel parking manoeuvres. [1]

High speed lane changing

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

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

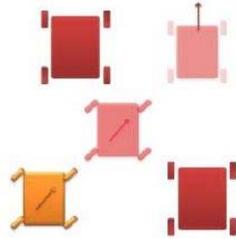


Fig. 2 High speed lane change maneuvers. [2]

The company **Honda Prelude [3]** manufactured the first four wheel steering car and it defines four wheel steering as the effect of the 4WS mechanism acting in this way was non-linear steering. That is, the effective steering ratio varied from a low ratio at small steering angles, to high ratio at large angles. This means more steering angle input is required to perform a gradual turn, making the car less twitchy and more relaxed to drive at high speed, without requiring constant corrections; while less steering angle is required to perform a tight-radius turn, giving the car a go-kart like feel during tight maneuvers. The observed effect while driving might be best imagined as a variable effective wheelbase, from a long wheelbase at small steering angles, to very short wheelbase at large angles.

Sano [4] conducted experiment and calculated for the turning radius and suggested low speed turning performance is improved by steering the rear wheels out of phase with the front wheels to reduce the turn radius, thus improving maneuverability. Normally the rear wheel steer angles are a fraction of that at the point (typically limited to about 5 degrees of steer) and may only be applied at low speeds. At 50 percent rear steer angle, a one third reduction in turn radius is achieved. At 100 percent rear steer angle, a 50 percent reduction in turn radius occurs.

The primary advantage of 4WS is derived from the better control of transient behaviour in cornering. In general 4WS systems yield a quicker response with better damping of the yaw oscillation that occurs with initiation of a turn.

3. PROBLEM DEFINATION

Nowadays all vehicles uses two wheel steering system, but the efficiency of the two wheel steering (2WS) vehicle is proven that it is still low compared to the four wheel steering (4WS) system car. So, this project is base on how to prove that the 4WS is better than 2WS in terms of turning radius.

A vehicle with higher turning radius face difficulty in parking and low speed cornering due to its higher wheelbase and track width, but the passenger prefer the vehicle to be higher wheelbase and track width as it gives good comfort while travelling. In this scenario four wheel steering will be effective as the turning radius will be decreased for the same vehicle of higher wheelbase. In this project a benchmark vehicle is considered and four wheel steering is implemented without change in dimension of the vehicle and reduction in turning radius is achieved. For achieving

reduction a mechanism is built which turns the rear wheels opposite to the front wheels.

3.1 Methodology

- Literature review on effect of implementing four wheel steering system on turning radius and maneuverability of a car are carried out by referring journals, books, manuals and related documents.
- The four wheel steering system model was built using ADAMS software and simulations carried out to know the turning radius and maneuverability.
- Four wheel steering physical model was built considering same stub axle for front and rear.
- CRC test was conducted to analyze maneuverability of the model.
- Turning radius comparison were made between the physical model and the ADAMS model.

4. CALCULATION [5]

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

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

We know that

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

Where R = Turning radius of the vehicle.

a_2 = Distance of CG from rear axle.

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

To find a_2

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

Where W_f = Load on front axle.

W = Total weight of car.

L = Wheelbase.

So from equation 2 and 1

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

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

To find steering angles;

From test we found that the inner angle of front tire is, $\delta_{if} = 25.6^\circ$.

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

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

Where C_1 = Distance of instantaneous centre from front axle axis.

C_2 = Distance of instantaneous centre from rear axle axis.

w_f = Front trackwidth.

From equation 3 and 4

$$C_1 = 1722.19 \text{ mm.}$$

$$C_2 = 452.80 \text{ mm.}$$

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

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

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

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

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

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

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

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

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

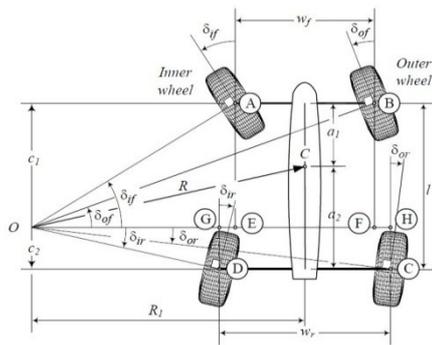


Fig. 3 Steering angles position of instantaneous centre for turning radius 4.4m. [6]

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

Calculation for turning radius for same steering angles.

To find turning radius, R

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

Where δ = Total steering angle of the vehicle.

To find δ

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

Where δ_i = total inner angle of the vehicle.

δ_o = total outer angle of the vehicle.

$$\cot \delta = 1.032.$$

From equation 8

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

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

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

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

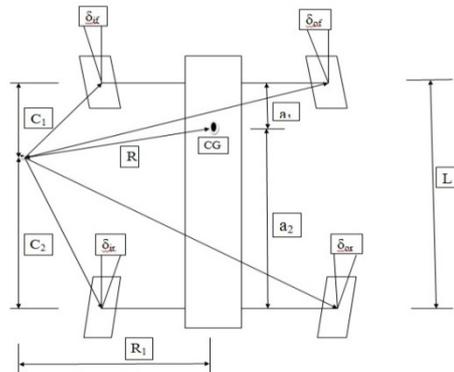


Fig. 4 Steering angles and position of instantaneous centre for turning radius 2.59 m

From Figure 8 and 9 we can see that there is a change in instantaneous centre as there is change in turning radius. The values of C_1 and C_2 changes gradually, in figure 3 the value of C_1 is greater and the value of C_2 is lesser but in Figure 4 as the turning radius changes the values of C_1 becomes lesser and the value of C_2 becomes more, this justifies that there is change in instantaneous centre, so there is change in turning radius. From change in instantaneous centre and calculations we conclude that for same wheelbase and track width there is change in turning radius from 4.4 m to 2.59 m.

4.1 Design of Model

The model is designed considering the same wheel base and track width as Maruti Suzuki 800. The model is designed using the software CATIA V5.

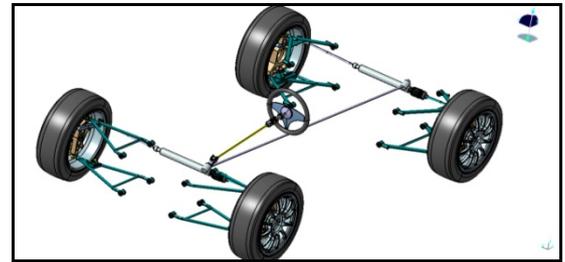


Fig. 5 Designed CATIA model

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

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

4.2 Final Model After Creating Joints

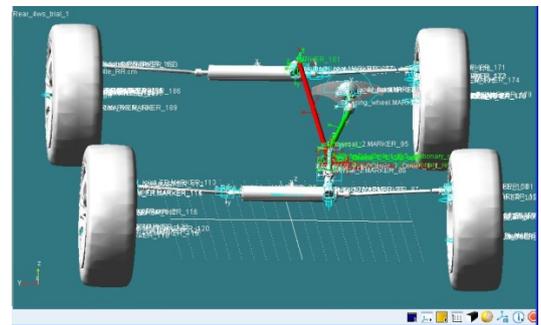


Fig. 6 Final model after creating the joints

Figure 11 shows the final model after creating all the joints with respect to all parts. The joint given for front steering is replicated at the rear steering, there is bevel gear joint provided between steering column and intermediate shaft. This intermediate shaft provides the rotation moment to the rear steering through rear body,

the shaft gets the rotational moment from the bevel gear and this bevel gear gets the rotational moment from steering column.

Table 1. Joints connected to the parts

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

4.3 Simulation of Four Wheel Steering

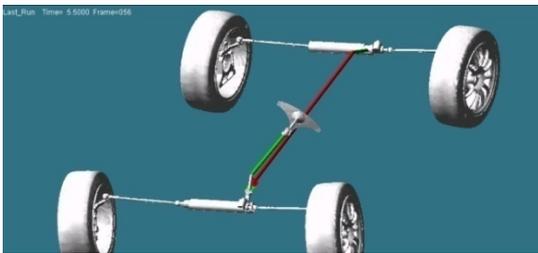


Fig. 7 Simulation of four wheel steering

After creating all the joints the simulation is carried out for the model. The motion is given to the steering wheel from that motion the vehicle turns with the help of the other parts and joints. From the figure 12 we conclude that all the four wheels are turning at an angle, the front wheels turn as per the steering wheel turns and the rear wheels turn opposite to the front wheels, as per the calculation and theory the concept of four wheel steering is proved from the simulation.

5. DESIGN OF FRAME

For building of prototype model, the designed model is considered along with that a frame is built to support the steering, suspension and seat.

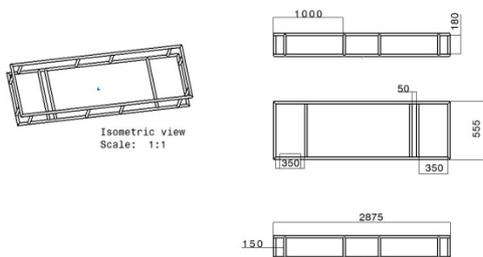


Fig. 8 Design of frame

The frame is designed considering the wheelbase and track width of Maruti Suzuki 800 and also it has to support for the suspension part as the suspension is welded to the frame, seat is also welded to the frame, the support structure for steering column and rack body is welded to the frame. The frame also takes the road

load and load of the driver, so considering all the factors the frame is designed and developed.

5.1 Equipment Required

1. Two sets of Maruti Suzuki 800 rack and pinion steering gear box and column.
2. A pipe of 25.4 mm diameter with 2 mm thickness.
3. Two bevel gears.
4. Four tires of Maruti Suzuki 800 of dimension 145/70R12.
5. Two sets of stub axle of front tires of Maruti Suzuki 800.
6. One steering wheel of Maruti Suzuki 800.
7. Two tie rods of Maruti Suzuki 800.
8. A solid rod of 19 mm diameter of 1.5 m length.
9. A square steel sheet of 400 mm x 400 mm of 2 mm thickness to act as seat.

5.2 Change from 2ws to 4ws

The model is built such that it can be changed from four wheel steer to two wheel steer when ever required. This four wheel steer is designed only for the parking purpose, so when the vehicle has to move at a speed higher than 10 kmph it has to be in two wheel steer so the vehicle is designed such that it can be converted to four wheel steer in parking and again back to two wheel steer when the vehicle crosses over 10 kmph. For changing from four wheel steer to two wheel steer there are two tie rods connected to frame as shown in figure 9. By the help of this tie rod we can change from four wheel steer to two wheel steer.



Fig. 9 Tie rods for converting from four wheel steer to two wheel steer

5.3 Final Model



Fig. 10 Final prototype model

Figure 10 shows the final prototype model, the model is built considering all the materials specified. This model is tested for constant radius test to check the reduction in turning radius and compared the result with the theoretical value obtained.

5.4 Two Wheel Steer

Figure 11 shows the model is in two wheel steer, the tie rod which is connected to the frame is connected to the stub axle of the rear so that the four wheel steer is neutralised and it is in two wheel steer. We can see in figure 4.5 that only front wheels are at an angle after steering but rear wheels are at straight ahead position. Constant radius test is conducted considering two wheel steer to check the turning radius of the prototype model. After conducting the test the turning radius we got is 5.75 m, but according to the benchmark vehicle it has to be 4.4 m. There is an error of 23.47%, the reason behind this error is the wheel balancing is not proper as well the suspension design was showing an error. The camber angle of front right tire is more compared to the front left tire, also there was a bit of toe out of the front wheels. So these factors affected the performance of the vehicle while turning and resulted in the increase of turning radius of the vehicle by 23.47%.



Fig. 11 Two wheel steer of the prototype model

5.5 FOUR WHEEL STEER



Fig. 12 Four wheel steer of prototype model

Figure 12 shows the four wheel steering of prototype model. The tie rod connected to the frame and the rear stub axle is removed and the tie rod connected to the rear steer rack is connected to the rear stub axle such that the two wheel steer is converted into the four wheel steer. After converting it constant radius test is conducted for the four wheel steer to check the reduction in turning radius. By test the turning radius we got is 2.85 m, so the reduction in turning radius is 50.43%. But as per the calculation the reduction in turning radius is 41.13%, we got 9.3% more reduction than calculated value, as the turning radius of two wheel steer is also 23.47% more in this prototype model. By

this test we can conclude there is a reduction in turning radius.

6. DISCUSSION OF RESULTS

6.1 Front Left Wheel v/s Steering Wheel

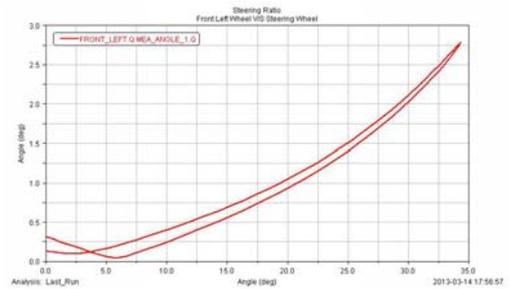


Fig. 13 Front left wheel versus steering wheel

Figure 13 shows the plot between the front left wheel of the model with the steering wheel of the model, as the steering wheel rotates the front wheel rotates at an angle and this ratio of rotation of angle is called steering ratio. According to the Maruti Suzuki 800 the steering ratio is 14:1, so considering this we have developed a model. In analytical model, the model is given a step function to turn a maximum of 35 degree, so considering 35 degree and steering ratio of 14:1, the angle the tire has to turn is 2.5 degree. But this front left wheel is turning at 2.8 degree, even though it has to turn 2.5 degree its turning more because when vehicle taking a left turn, front left wheel is the inner wheel so it has to turn more degree than the other front wheel. This result proves that the inner tire is taking more turn.

6.2 Front Right Wheel v/s Steering Wheel

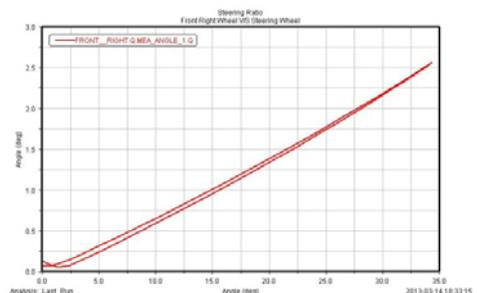


Fig. 14 Front right wheel versus steering wheel

Figure 14 shows the plot between front right wheel and steering wheel, here the right wheel is turning at an angle of 2.6 degree which is 0.1 degree more to the theoretical calculation, when vehicle is taking a left turn this right wheel is the outer wheel and it has to take less degree of turn. The reason behind more degree of turn is the camber angle is more to the right wheel and it's been toe out at an angle, so the right tire is taking more angle. By adding both angles of front right and front left tires we should get a sum of 5 degree but here we are getting 5.4 degrees which is 0.4 degree more, so the error is 0.07%. According to the calculation the front left tire should turn 2.2 degree but it is turning 2.6 degree and the error is 15.38%.

6.3 Rear Left Wheel v/s Steering Wheel

Figure 15 shows the plot between rear left wheel and steering wheel, here the left wheel is turning at an angle of -2.7 degree, the negative sign indicates the rear wheel is turning in opposite direction to the front wheels. The vehicle is taking a left turn so in this case the left wheel will be outer wheel.

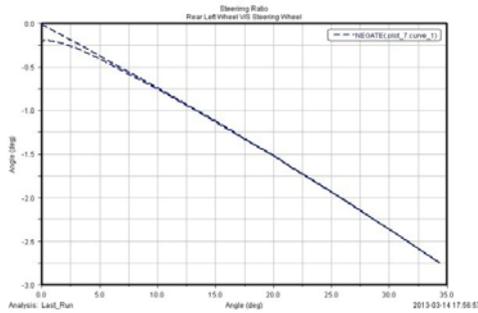


Fig. 15 Rear left wheel versus steering wheel

As per the calculation this left wheel should not cross a maximum angle of -2.5 degrees but it has taking -0.2 degree more turn, the reason behind more turn is the rear left wheel has more slip angle, due to this slip the camber is more and it's taking more turn than expected. The error percentage is 0.07%.

6.4 Rear Right Wheel v/s Steering Wheel

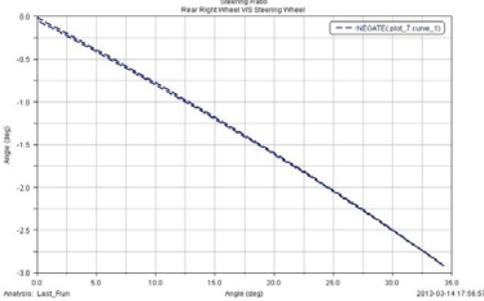


Fig. 16 Rear right wheel versus steering wheel.

From Figure 16 shows the plot between rear right wheel and steering wheel, here the right wheel is turning at an angle of -2.9 degrees. The vehicle is taking a left turn so in this case the right wheel will be inner wheel. As per the calculation this right wheel should not cross a maximum angle of -2.8 degree but it has taking -0.1 degree more turn, as the left wheel is taking more turn due to this right wheel also taking more turn, the error is 0.03%.

6.5 Rear Wheels v/s Steering Wheel

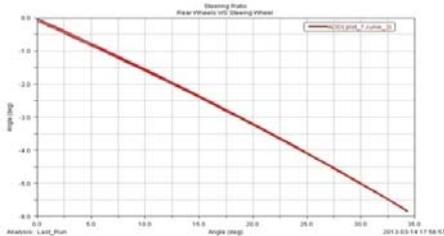


Fig. 17 Rear wheels versus steering wheel.

Now considering both the left wheel and right wheel the angle the rear wheels should turn at an angle of -5 degrees, but from figure 17 we see that summing of both angles its crossing -5 degree and reaching -5.8 degrees i.e (-0.8 degrees more). The error found was 0.13%. Comparing the rear wheels total angle with front wheels total angle, the front wheels total angle is 5.4 degree and the rear wheels total angle is -5.8 degree by negative sign we can say it's turning in opposite direction but there is 0.4 degree difference between both wheels. According to the calculation rear wheels should turn at same angle as the front wheels in opposite direction but here rear wheels are taking 0.4 degree more turn, the reason is there is more slip angle and this slip is 0.4 degree. By this we can conclude that for the slip angle of 0.4 degree the rear wheels are taking 0.4 degree more turn.

6.6 Constant Radius Test

Constant radius test is conducted for two wheel steer and for four wheel steer, first the tie rod connected to frame is connected to rear stub axle and constant radius test is conducted, then the tie rod is removed and tie rod of rear steer is connected to the rear stub axle and test is conducted for the four wheel steer. For measuring the circle formed by the vehicle, a rod is placed at the centre of the vehicle and it is measured by the measuring tape.

Figure 18 and 19 shows the constant radius test conducted for two wheel steer and four wheel steer. The circle represents the turning diameter of the vehicle, for two wheel steer the circle diameter is 11.5 m and for four wheel steer the circle diameter is 5.7 m. So turning radius of two wheel steer is 5.75 m and for four wheel steer 2.85 m.

CRC test for two wheel steer



Fig. 18 Constant radius test conducted for two wheel steer.

CRC test for four wheel steer



Fig. 19 Constant radius test conducted for four wheel steer.

6.7 Comparison



Fig. 20 Comparison circle of 2WS and 4WS

Table 2. Comparison for two wheel steer and four wheel steer

Turning radius	Four wheel steer	Two wheel steer
By calculation	2.59 m	4.4 m
By experiment	2.85 m	5.75 m

Table 2 gives the comparison between the turning radius for two wheel steer and four wheel steer by calculation and experiment. By calculation we can conclude that there is 41.13 % reduction in turning radius and by experiment it's 50.43%.

7. CONCLUSION

By the analytical and experimental analysis and results we conclude that;

- Four wheel steering concept was generated
- The four wheel concept was simulated in ADAMS to check for functionality of mechanism

- Working prototype was built to carry out CRC tests and to find the reduction in turning radius with four wheel steering when compared to two wheel steering
- The results from CRC tests are as follows: Turning radius achieved with two wheel steering is 5.75m and turning radius achieved with four wheel steering is 2.85m.
- By experiment the reduction in turning radius with four wheel steering when compared to two wheel steering is 50.43%.

8. REFERENCES

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