Optimization and Mathematical Calculation of Turning Radius for 4 Wheel Steering Systems in Maruti Suzuki Baleno

Sapam Subaschandra Singh, Gagandeep Singh Mavi

Abstract: *Understeering in production vehicles is a common mechanism followed in day to days automobile industries. Rare cases have been recorded where over steering is implemented. Consider a vehicle that can automatically compensate for both the under steering and over steering issues, the concept will assist and enable the driver to experience nearly the neutral steering under the varying operational conditions. This paper deals with the introduction of rack and pinion mechanism, employed for the purpose of optimizing and mathematical calculation of turning radius for a 4 Wheel steering system equipped in the considered vehicle model MARUTI SUZUKI BALENO. This allows the conversion of the steering rotational motion into linear motion which enables effective wheel turning with minimum efforts applied by the driver. The power is transferred from the front axle to the rear axle by using a tie rod connected to a rack and pinion mechanism. The excessive work load on the front wheels and uneven tire wear results in a less efficient functioning of the vehicle. The purpose of this paper helps in enhanced and much efficient performance of the vehicle and reduces the maneuverer efforts.*

Keywords: *Optimization, 4 Wheel steering system, Rack and pinion mechanism, Ackerman angle, Tie rod etc.*

I. INTRODUCTION

In order to achieve higher maneuverability at high speeds and to reduce the turning radius of the vehicle which reduces the driver`s efforts while turning, vehicles are equipped with 4 Wheel steering system. K. J. Yogesh (2007) designed and fabricated a 4 Wheel steering mechanism which assists in improving maneuverability in vehicles with four wheels. This implies that the rear set of wheels follows the path of the front set of wheels. High efficiency in achieving in-out phase rear steering with respect to front wheels was observed in the fabricated design. Upon developing a mechanical linkage between both the axles using rack and pinion steering system in order to decrease the turning radius of the vehicle with four wheels, V. Arvind (2013) was able to calculate the turning radius for a vehicle with and without four-wheel steering mechanism and compared the effects. It was found that the turning radius reduction can be done by up to 35% using 4 Wheel steering.

Saket (2014) introduced a double rack and pinion system for rear wheels enclosed within a casing to further improve maneuverability of a vehicle and decrease the steering effort of the driver. The movement of rear pinions was set to control the movements of the rear wheels to achieve the required movements of the rear wheel by moving the spindle. It was observed that the developed system assisted in high speed lane changing. Krishna Bevinkatti (2015) developed quatra steering system by conceptualizing a four-wheel steering system by making steering possible for both the set of wheels of a vehicle. At high speeds, stability, handling and control work increased while at low speed, ease of driving was observed. Ansari Rehan (2017) analyses the steering mechanism and designed a mechanism capable of turning all the four wheels of a vehicle simultaneously despite of the direction, to utilize the steering system in a much efficient manner. Maruti Suzuki 800 was considered for the experimental purpose.

In most active 4 Wheel steering systems, the guiding computer, sometimes also referred to as an electronic equipment has an important role to play. In this work, the mechanism has been kept as much simple and mechanical as possible making it easy to manufacture and maintain.

II. MATERIAL

Maruti Suzuki Baleno model 2019 was considered for the experimentation purpose as it is equipped with the four-wheel steering system. The model is represented in the figure 1 a) and figure 1 b), shown as:

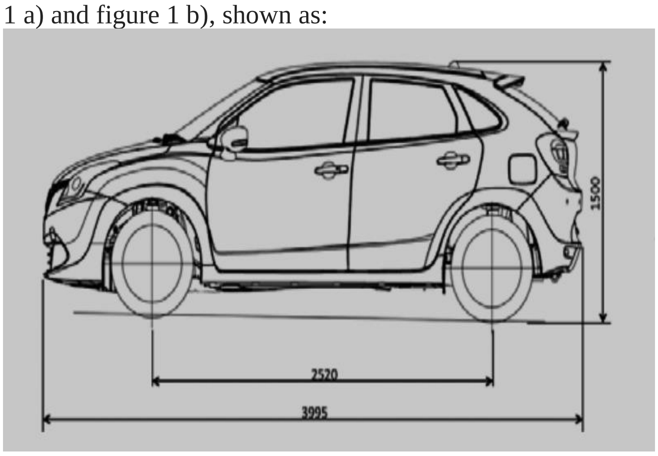

Figure 1 a). Maruti Suzuki Baleno benchmark values

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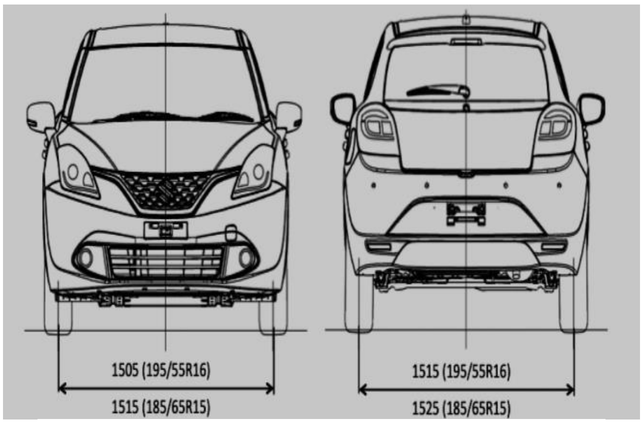

Figure 1 b). Maruti Suzuki Baleno benchmark values

2.1 Baleno car specification for 2 Wheel steering system

Table 1 shows the specification of the vehicle with 2 Wheel steering system.

Standard	Dimensions
Wheel base (L) mm	2520
Track width front (w_f) mm	1515
Track width rear (w_r) mm	1525
Weight of the car (kg)	935
Weight distributions (front: rear)	60:40
Turning radius (mm)	4900
Kingpin center to center distance (mm)	1315

III. METHODOLOGY

Method that is to be implemented in 4 Wheel steering system includes:

For turning the steering wheel, Ackerman steering method or Ackerman principal is used.

From the Ackerman principal or steering method, Ackerman Arm Angle is mathematically shown by,

$$\tan^{-1}\left[\frac{\text{kingpin center to kingpin center distance}/2}{\text{wheel base}}\right] = \beta$$

Also, Ackerman angle (α)

$$\sin\beta = \frac{(\text{kingpin center} - \text{center distance}) - (\text{length of the tie rod})}{2R}$$

For finding the method of tie-rod and arm radius from figure 2, shown as:

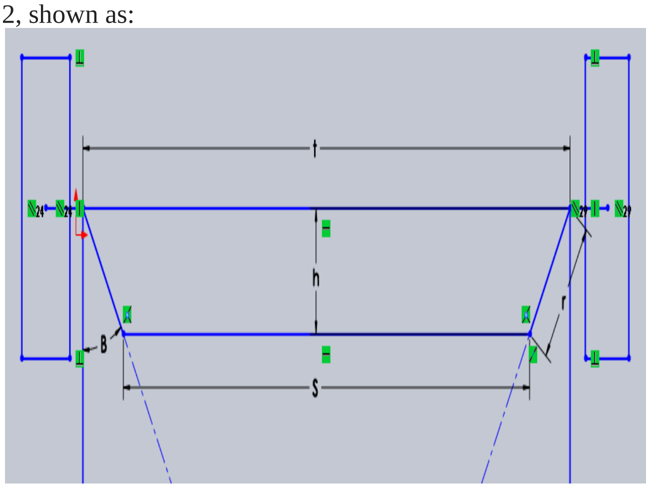

Figure 2. Schematic for finding tie-rod length and arm radius

$$\beta = \tan^{-1}\left[\frac{t-s}{2h}\right]$$

$$r = \tfrac{1}{2}\sqrt{(t-s)^2 + 4h^2}$$

$$h = r\cos\beta$$

$$s = t - 2r\sin\beta$$

Theoretical calculation for the verification of the radii of all the four wheels and calculation of turning circle radius is to be done,

- Calculation of position of centre of gravity with respect to the real axle
  $R^2 = a^2 + R_1^2$
- To find a_2
  $W_f = (W*a_2) / L$
- Calculation of instantaneous centre from both axles is done as:

Figure 3 refers to the schematic to find position of instantaneous center

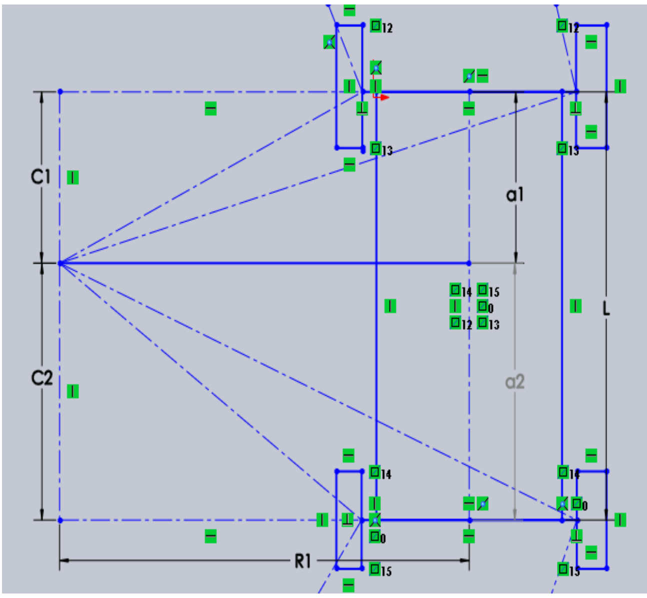

Figure 3. Schematic to find position of instantaneous center

- To find the lock angles

$\tan\theta_{if} = [C_1 / (R_1 - w_f / 2)]$

$\tan\theta_{of} = [C_1 / (R_1 + w_f / 2)]$

$\tan\phi_{ir} = [C_2 / (R_1 - w_r / 2)]$

$\tan\phi_{or} = [C_2 / (R_1 + w_r / 2)]$

Where,

C_1= Instantaneous center to front axle axis distance

C_2= Instantaneous center to rear axle axis distance

- Keeping the steering angle same for front and rear wheels, turning radius of the vehicle can be calculated while keeping the wheelbase and track width same as that of the benchmark vehicle.
- Calculation method to find the turning radius `R` at same steering angle,

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

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IV. RESULTS

Upon undergoing the analysis of the problem, the solution for decreasing the turning radius has been calculated. It has been found that, the methodology in the research project opted may be one of the possible operational sets.

3.1 Comparison between 2 Wheel steering and 4 Wheel steering.

Conduction of experiment on the considered vehicle model for the desirable outcome to be achieved, the benchmarks were set to the basics, as already specified by the manufacturer. For 2 Wheel and 4 Wheel steering systems, the experimental turning radii calculated were 4.9m and 2.9m, respectively.

Given the validity of the results obtained, simulation using SolidWorks software was also carried. No difference was observed in the calculated and the experimental results in two-wheel steering system. However, a very minute difference was seen to occur in case of four-wheel steering systems. The experimental value exceeds the value obtained through simulation.

Table 2 Compares the experimental and theoretical calculations in 2 Wheel and 4 Wheel steering systems.

Turning radius	Two-wheel	Four-wheel
By calculation	4900mm	2700mm
By experiment	4900mm	2900mm

After decreasing the turning radius, it has been found to be comfortable for the vehicle to move more easily for parallel parking, U-turns, driving in narrow road, junction and gentle curves. This also makes the vehicle comfortable for both the driver and the passenger. The successful implementation of 4 Wheel Steering system using mechanical linkages & single actuator resulted in the development of a vehicle with maximum driver maneuverability, uncompressed static stability, front and rear tracking, vehicular stability at high speed lane changing, smaller turning radius and improved parking assistance. The calculated turning radius using SolidWorks 2012 was found to be equivalent to that calculated experimentally. The benchmark used in the work does not limit the functioning of the developed system and can be implemented widely in almost all the automobile ranges, whether trucks or hatchbacks.

V. CONCLUSION

Relatively new technology, 4 Wheel steering system imposes the feature of maneuverability in trailers, truck and cars. However, the rear set of wheels in standard 2 Wheel steering vehicles is always directed forwards thus no active role is played in controlling the steering in 4 Wheel steering system. The rear wheel can however turn left and right in order to keep the driving controls as simple as possible.

It has been found that the aim of four-wheel steering to achieve a better stability during overtaking maneuvers, reduced sensibility to lateral wind etc. has been achieved.

Vehicle development with maximum maneuverability, comparatively smaller turning radius, speed lane changing stability and front/rear tracking was achieved upon successfully implementing the concept of 4 Wheel steering system by using mechanical linkages. The benchmark used in the work does not limit the functioning of the developed system and can be implemented widely in almost all the automobile ranges, whether trucks or hatchbacks.

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Sapam Subaschandra Singh is currently pursuing Master in Engineering, Mechanical Engineering at Chandigarh University, Gharuan, Punjab with CAD/CAM and Robotics as specialization and has completed his Bachelor`s degree in Mechanical Engineering from Maharaja Agrasen University, Baddi, Himachal Pradesh.

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