Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 05, May-2025

Design of Steering Geometry for FSAE Car

Iniyavan P
Student, Department of Mechanical Engineering,
Thiagarajar college of engineering, Madurai, Tamil Nadu, India

Abstract:
Steering is an important part of an automobile. It helps to change the directions of the automobile and also helps in the straight line's stability of the vehicle. This report focuses on mathematical modelling and design of a rack and pinion steering mechanism of a formula student vehicle. We have developed a set of mathematical equations that governs the complete design of steering and later prepared the CAD model. By solving these equations, we can get different steering geometry parameters by fixing some variables according to restriction and considering optimum steering geometry with respect to steering effort and percentage Ackerman.

I. INTRODUCTION:

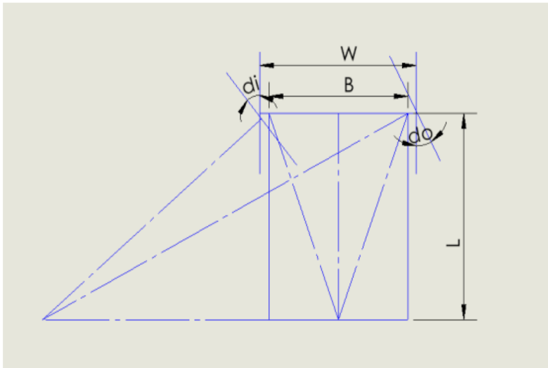
Steering mechanism is designed in a way that it meets the Ackerman principle i.e. in order for a vehicle to perform a pure turning, the I-centre of all the wheels should meet at one single point. We have achieved this condition using rack-and pinion gear box in our project. The pinion gear is rotated when the steering wheel is rotated. The output shaft from the steering wheel and the input shaft to the pinon gear are connected by a universal coupling. The rotational motion of the pinion gear causes the rack to move transversally which in turn pushes the tie-rod and the tie-rod helps the wheels to turn by pushing the steering arm.

II. STEERING GEOMETRY MODEL:

The image below shows the steering geometry and the value of it' s important parameters. Our motive is to design Ackermann steering Geometry, so that the inner wheel turning angle more than the outer wheel. By this sketching this diagram in Solid works we can compute outer wheel turning angle and Turning radius using Measuring tool in Solid works.

Where:
W = Track width
B = distance between left and right knuckles
L = Wheel base of the vehicle
do = outer wheel angle
di = inner wheel angle

Fig 1: Geometrical parameters



Using the basic laws of trigonometry we arrive at the following equation:

$$\cot d0 + \cot di = B/L$$

This is the Ackerman condition for a two-wheeled steering. When Ackerman condition is satisfied in a steering mechanism the vehicle takes a turn. The inner wheel needs to be turned more than the outer wheel in order for the condition to be satisfied.

Table 1: Parametric values of Geometry

PARAMETERS	VALUES
Wheel Base(L)	1600.2mm or 63inch
Front track width(W)	1200mm
Rear track width(w)	1150mm
Left knuckle steering point to Right knuckle steering point(B)	1040mm
Ackermann angle(β)	18 degrees
Inner wheel turning angle(ɵ)	40 degrees
Outer wheel turning angle(ɵ1)	29.75 degree
Tie rod length(y)	317.51 mm
Ackerman arm length(x)	90mm
Distance between front axis and rack axis(d)	100mm
Length of rack(z)	350mm
Steering Ratio	*4:1*

Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 05, May-2025

III. RACK TRAVEL(A) AND CALCULATION

Rack Travel is defined as the distance the rack travel for the full turning of a tyre on one side (left or right). The mathematical equation to calculate rack travel(α) is given by:

$$\propto = x\sin(\theta+\beta) - \left(\frac{B-Z}{2}\right) + [y^2 - (d - x\cos(\theta+\beta))^2]^{0.5}$$

By using this equation, the calculated rack travel**(α) = 44.49mm**

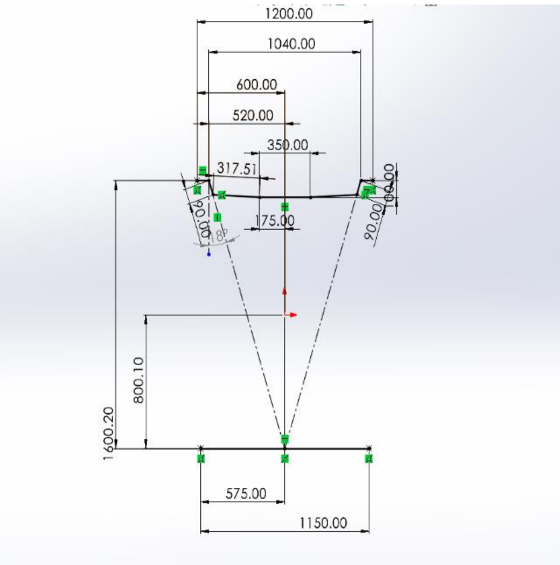


Fig 2: Steering geometry 2-D sketch

IV. PINION CALCULATION

Now the rack travel for 1 degree turn of tyre(δ) is given by,

$$\delta = \alpha/\theta \qquad (1)$$

Now our steering ratio is 4:1 so, for 1 degree turn of tyre we need 4 degrees rotation in steering wheel. So, the rack travel for 1 degree turn of tyre(δ) can be calculated by using,

$$\delta = r.\omega \qquad (2)$$

Where;

$\omega = 4° * (\frac{\pi}{180})$
r = radius of pinion

By equating the equations (1) and (2);

r = 15.94mm

r ≈ 16mm

Diameter of pinion(D) = 2r

D = 32mm

Now by referring the Gear terminology and Nomenclature, for pinion diameter 32mm and steering ratio of 4:1, ***Module(M)*** is decided.

M = 2mm

No of teeth on pinion (T_P) = $\frac{D}{M}$

T_P = 16 teeth

Addendum = 1M = 2mm

Dedendum = 1.2 M = 2.4mm

Working Depth = 2M = 4mm

Total Depth = 2.2 M = 4.4mm

Clearance = Total Depth – Working Depth

= 4.4 – 4

Clearance = 0.4mm (between rack and pinion)

Thickness of the Teeth = $D(\sin 90°/T_P)$

Thickness of the teeth = 2mm

Circular pitch = π*M

Circular pitch = 6.28mm

No of teeth on rack = **T_R** = $\frac{\delta_T}{\pi * M}$

T_R = 14.1687 ≈ 14mm

For manufacturing feasibility ***T_R = 16 teeth***

Actual total length of rack (L_R) = T_R * π*M

L_R = 100.48 mm

Steering Effort Calculation:

Total weight of car = 260kg

Weight distribution = 51.4% in front and 48.5% in rear

Weight on front two wheels(front)= 0.514(260)

= 133.64 kg for two wheels

P = 66.82 kg for one wheel or 655.50 N

Resistance Force (R_F) = $\mu * P$

= 0.6 * 655.50

R_F = 393.3 N

Resistance Torque on tyre (R_T) = $R_F * S_r$
where S_r = scrub radius = 50mm

= 393.3 * 50

R_T = 19665 N-mm

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 05, May-2025

To calculate the force to be applied on the Ackermann arm(F) by the rod

$$F = \frac{R_F * S_r}{i}$$

where i = horizontal distance of Ackermann arm=8.59mm

F = 229.758mm

Required torque at steering wheel (T) is:

$$T = P * \left(\frac{D}{2}\right)$$

T = 3676.128 N-mm

Required steering effort (S_e) = $\frac{T}{R}$

where R = radius of steering wheel = 125mm (Assumed)

= 3676.128/ 125

S_e = 29.409 N (In stationary condition)

Table 2: Final values of Steering system

PARAMETERS	VALUES
Rack travel for full left or right turn	44.49mm
Pinion diameter	32mm
Module	2mm
No. of. Teeth on pinion	16 teeth
Clearance between rack and pinion	0.4mm
Thickness of the teeth	2mm
Circular pitch of pinion	6.28mm
Axial pitch of rack	6.28mm
No. of. Teeth on rack	16 teeth
Length of rack (Actual)	100.48mm
Steering Effort	29.409 N (stationary condition)

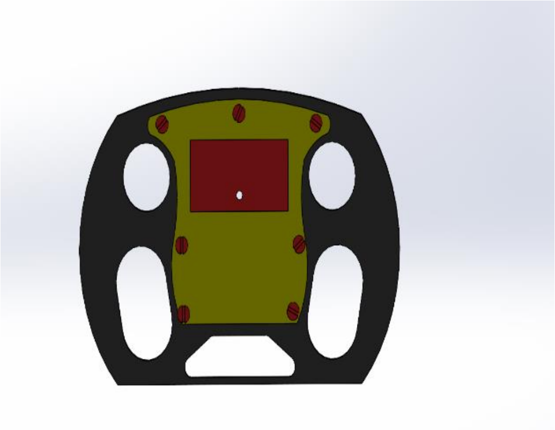


Fig 3: Front view of Steering wheel

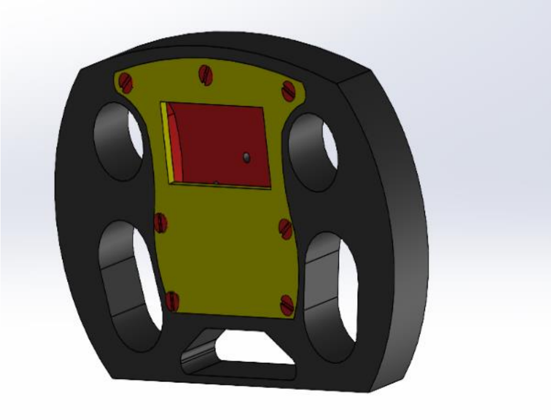


Fig 3: Isometric view of steering wheel

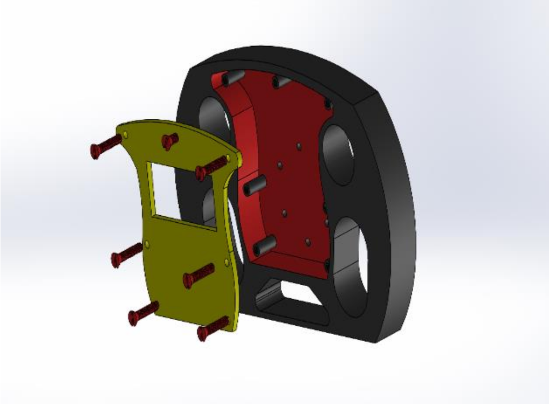


Fig 4: Exploded view

V. REFERENCES

[1] Race Car Vehicle Dynamics – William F. Milliken & Douglas L. Milliken [ISBN: 978-1560915263]
[2] Tune to Win – Carroll Smith [ISBN: 978-0879380717]
[3] V B Bhandari, Design of Machine Elements, Third edition, McGraw Hill Education, India, 2010.
[4] McRae, John and Potter, James Jackson, "Design Considerations of an FSAE Steering System" (2019). Mechanical Engineering and Materials Science Independent Study. 94. https://openscholarship.wustl.edu/mems500/94.
[5] R. Rajamani, Vehicle Dynamics and Control, 2nd ed., New York, NY: Springer, 2012. [Online]. Available: https://link.springer.com/book/10.1007/978-1-4614-1433-9
[6] R. Rajamani, Vehicle Dynamics and Control, 2nd ed., New York, NY: Springer, 2012. [Online]. Available: https://link.springer.com/book/10.1007/978-1-4614-1433-9