

# Selection & Design Procedure of Steering System of Formula Student (FSAE) Car

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**Abstract** – The main objective of this paper is to give detailed review of Formula Student Vehicles steering mechanism. Realistic approach of geometry selection for steering mechanism is followed by designing with the help of Solid Works 2017. The steering ratio, turning radius, steering efforts, front wheels turning angles and Ackermann percentage are optimized in Lotus Shark and ADDAMS. The goal of designing and optimizing the steering mechanism is to provide good directional stability and full control over the vehicle even on the sharp hair pin turns. All the design obeys the rules stated by the FSAE rulebook and FORMULA BHARAT rulebook 2019.

**Key Words:** Ackermann steering, Steering ratio, C-factor, Rack position

## 1. INTRODUCTION

The steering system of formula SAE car is one of the important task. As the steering help the driver to control vehicle however he wants. The steering provides good stability to vehicle on road. It is combine effect of the all linkages by efforts gives by driver to wheels which results to high speed on the track.

So as to design and manufacture the steering system for Formula SAE vehicle as per the rule book of SUPRA SAE India 2018 and Formula Bharat 2019. The steering provide pure rolling motion to wheel and fulfil the requirements of steering to take the sharp turn on the track.

## 2. STEERING GEAR MECHANISM

### 2.1 Davis Steering Gear Mechanism

In Davis steering there are sliding guides attached to rack setup and these guides slide on the rods extended from wheel hub king pin. Davis steering is operated from front side wheels. This mechanism causes friction between rod and guides, thus increase steering effort.

### 2.2 Ackerman Steering Mechanism

In Ackerman steering, the sliding pairs of Davis steering are replaced by all the turning pairs. Basically the Ackerman

steering mechanism reduces the friction and also reduces the steering effort and help to take more sharp turns.

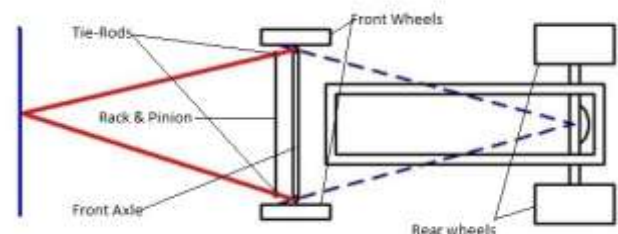
$$\sin(\alpha + \theta) = \frac{y + x}{r}$$

$$\sin(\alpha - \varphi) = \frac{y - x}{r}$$

$$\sin(\alpha + \theta) + \sin(\alpha - \varphi) = \frac{2y}{r} = 2 \sin \alpha$$

## 2.3 Anti-Ackerman Steering Gear Mechanism

The Anti-Ackerman steering is similar to Ackerman steering only difference is that the steering is operated from front side of the wheels. The steering provides more slip angles and help to take sharp turn.



## 3. SELECTION OF STEERING MECHANISM

**3.1** Davis or Anti-Ackerman steering system would difficult to steer at lower speed. By using Ackerman Steering mechanism, it helps to reduce the weight of the steering column and provides good directional stability. So, the Ackerman steering mechanism is selected.

## 4. STEERING GEOMETRY PARAMETER

As per FSAE Rule book wheelbase should be minimum 1525mm, & other following required parameters select by the FSAE guidelines.

**Table -4.1:** Steering Data

Front track width
Rear track width
Turning Radius
Inner wheel angle
Outer wheel angle

#### 4.1 STEERING RATIO

Steering ratio is the ratio of how much the steering wheel turns in degrees to turn the wheel by 1 degree

$$\text{Steering ratio} = \frac{\text{Turn of steering wheel in degrees}}{\text{Turn of wheel by 1 degree}}$$

Steering ratio depends on many factors like diameter of pinion, rack travel, steering wheel diameter, moment arm length etc.

#### 4.2 TURNING RADIUS

By changing the Ackerman setting of car the overall turning radius of the car can be adjusted. The turning radius of the vehicle was calculated based on ideal ackermann position to maximum. The car had wheelbase of 1600mm and the required turning radius up to 3.7m which is reasonable for expected hair pin turns on the formula auto cross race track.

#### 4.3. C-FACTOR

C-Factor is defined as length in mm travelled by rack for 360 degree rotation of pinon.

$$\text{C-Factor} = \frac{\text{Rack travel}}{\text{One pinon rotation}}$$

#### 4.4. RACK & PINION DESIGN

Rack & Pinion starts with the first basic step i.e. selection of the material which leads that improper material selection which cause failure.

In the design of gears, it is required to decide the number of teeth on the pinion and gear. There is a limiting value to the minimum number of teeth on the pinion. While decreasing the number of teeth, a point is reached when there is The tangential force on the gear (Pt) interference. Interference is non-conjugate action and results in excessive wear, vibrations and jamming. To avoid interference, minimum number of teeth for 20° full depth system required is 17. Using Lewis equation, the module is calculated. It predicted the chances of teeth interference. So, number of teeth on gear is increased to 21. And then again designed using Lewis equation and Buckingham equation.

Which is as follows

Factor of Safety (fs)-The recommended factor of safety is from 1.5 to 2

$$P_{\text{eff}} = \frac{C_s}{C_v} Pt$$

Tangential force on Gear:

$$= \frac{2 * \text{max.torque}}{\text{no of teeth} * \text{module}} = \frac{2 * Mt}{Z * m}$$

Beam strength of gear (Sb)

= Module\*face width\*maximum bending load\*Lewis form factor.

This equation is known as Lewis equation.

$$S_b = m * b * \frac{S_{ut}}{3} * Y_p$$

From these steps the gears is designed

$$M = \frac{\frac{C_s}{C_v} Pt * Fs}{b * \frac{S_{ut}}{3} * Y_p}$$

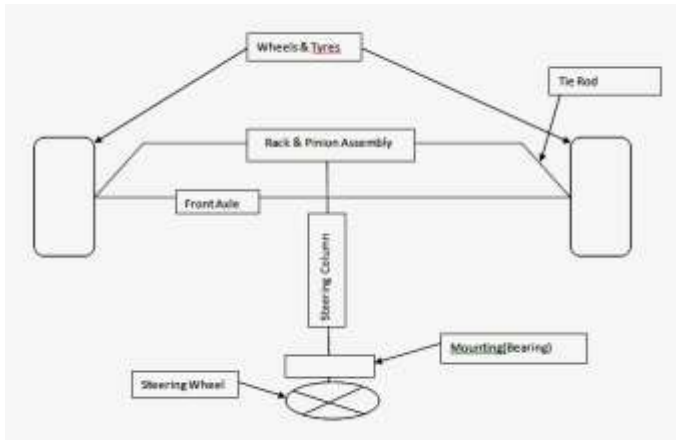
#### 4.5. RACK Position:

Rack is mounted behind the front wheel center line as per the geometrical, ergonomics and driver egress viewpoint. Rack position is optimized by observing the changes in steering radius, inner wheel and outer wheel angles as per the requirements.

Lotus shark software: -the Lotus Suspension Analysis SHARK module is a suspension geometric and kinematic modelling tool, with a user- friendly interface which makes it easy to apply changes to proposed geometry and instantaneously assess their impact through graphical results. Lotus shark software gives instantaneous results of inside angle (in degree) for a particular rack shift.

Rack shift or rack travel per rotation is the horizontal distance travelled by the rack gear when the pinion gear completes one rotation.

### 3. Final Steering System



### 3. CONCLUSION

Steering system used for student formula race car, different parameters should be considered like steering parameters, steering ratio, turning radius, C-factor. According to all these parameters, rack position is to be selected to fulfill the all requirement as overall analysis of Rulebook of FSAE & Formula Bharat.

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