Design of Steering System of FSAE Car

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Abstract - *FSAE is a student design competition where they have to design, build and test a formula style car. The main objective of this paper is to study the design of optimized steering system of FSAE car, which provide good steering response to the driver and ease in handling with increase in stability at higher speed. This system is designed according to set of rules stated by FSAE rulebook.*

***Key Words*: Steering System, Ackerman steering, Rack and Pinion, Steering effort**

1. INTRODUCTION

The main objective of the Steering system is to enable the driver to continuously maneuver the path of vehicle and provide good steering response to the driver. The steering system converts the rotational motion from the driver to the translatory motion of rack that results in angular turning of the wheels in desired directions, Also it is designed to provide mechanical advantage over the front uprights offering minimum steering effort in any desired direction.

2. SELECTION OF STEERING MECHANISM GEOMETRY

Steering geometry is arrangement of linkages with the requirement of reduced skidding of wheels and minimum turning radius, It is possible to achieve it with three geometries i.e., Parallel steering geometry, Anti Ackerman steering geometry and Ackerman steering geometry.

In parallel steering geometry the angle turned by the inner wheel and outer wheel are same, Parallel steering is quite unstable during the mid of corners that results in skidding. During Anti Ackerman steering due to higher slip angles the traction was more at the outer wheel while cornering and pulled the inner wheel outwards resulting in increased turning radius.

In Ackerman steering geometry each wheel has its own pivot near the hub, At turn the inner wheel and the outer wheel turn at different angles. The projection of steering arm which turns the wheel intersects at the center of rear axle, thus Ackerman steering resulted in no skidding of front wheels and also the stability increases, Thus Ackerman steering geometry is selected.

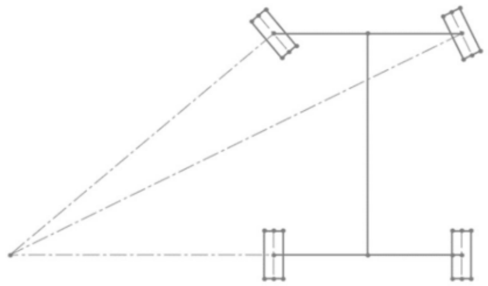

Fig -1: 100% Ackerman

3. STEERING GEOMETRY PARAMETERS

3.1 Steering effort

Steering effort is the force applied by the driver at the steering wheel to produce a torque that results in turning of wheels, to calculate the steering effort we require torque applied on the pinion.

$$Torque_{pinion} = \text{Net force transmitted by rack to tie rods} \times \text{Radius of pinion}$$

$$\text{Steering effort } (F_{driver}): Torque_{pinion} \times \text{Radius of steering wheel}$$

3.2 Steering ratio

Steering ratio is the ratio of angle turned by steering wheel to angle turned by wheels of car.

$$\text{Steering ratio} = \frac{\Theta_{\text{steering wheel}}}{\frac{\delta_r + \delta_l}{2}}$$

δ_r = Angle turned by outer wheel

δ_l = Angle turned by inner wheel

3.3 C-Factor

C-Factor is the distance travelled by rack per 360^0 rotation of the pinion

$$\text{C-Factor} = \pi . D_{pinion}$$

4. STEERING MECHANISM

The rotational motion of the steering wheel is transferred to the wheels of cars via suitable mechanism, the mechanism takes input from the steering column and transfers it to the tie rods connected to the wheels. Due to less weight and less space required Rack and pinion mechanism is selected, accordingly a custom rack and pinion is manufactured.

Fig -2: Manufactured Rack and pinion assembly

4.1 Calculations of rack and pinion gear

Initially we require rack travel on either side and pinion rotation with reference to suspension geometry

Rack travel: 39mm (one side)
Pinion rotation: 90^0 (one side)
Module= 1.5mm

Diameter of pinion:

$$\text{Rack travel} = \frac{\pi D_{\text{pinion}}}{4}$$

Diameter of Pinion= 49.65mm

Z_{Pinion} (No of teeth on pinion):

$$Z_{\text{pinion}} = \frac{D_{\text{pinion}}}{m}$$

Z_{pinion}=33

Z_{Rack}:

Z_{Rack}=Z_{Pinion}=33

Tooth Depth= 2.25 × module = 3.375mm

Addendum= 1 × module = 1.5mm

Dedendum= 1.25 × module = 1.875mm

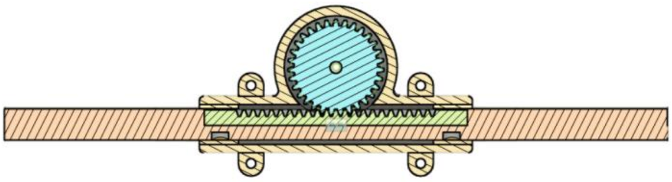

Fig -3: Sectional front view

Fig -4: Pinion

Fig -5: Rack

4.2 Location of Rack and pinion

Location of rack and pinion mainly depends on inversion of four bar mechanism and packaging, If the steering rack is placed behind the front axle it results in early inversion of linkages and restricts the turning of inner wheel and therefore turning radius is increased

If the steering rack is placed ahead of the front axle the point of inversion is pushed forward and desired turning angles are achieved, the rack and pinion gearbox height is increased slightly and is inclined at an angle toward the driver in order to achieve simple intermediate mechanism. The problem of packaging is solved by selecting rims with greater step offset as required.

4.3 Selection of Intermediate mechanism

If the steering wheel axis is directly aligned with the pinion axis there is no need of any intermediate mechanical joint between steering wheel and pinion, but some mechanical joint is used to angle the rotational force along new axis, this can be done by a universal joint.

Considering the position of rack and pinion and satisfying the 915 rule, the seating position of driver comply with rule, as we increased the height of gearbox and given angle of inclination, a single universal joint is selected which has less weight and high sensitivity at small turning angles as desired for autocross.

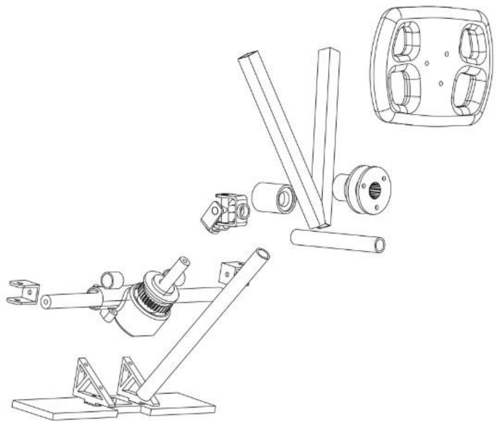

Fig -6: Exploded view of steering assembly

5. MATERIAL SELECTION

Selecting the appropriate materials considering the operating conditions, fatigue life decides the endurance limit of the component. Following are the considerations for components taken into account prior selection of materials

- Steering wheel: Sustain steering torque, should be lightweight and provide adequate grip.
- Quick release: high wear resistance.
- Column and universal joint: Steering torque.
- Rack and Pinion gear: bending load on teeth and wear resistance.
- Gearbox casing: rigid and lightweight.
- Tie rods: Tension, Compression and buckling under dynamic forces.

Components	Material	Manufacturing process
Steering wheel	Composite (Carbon fiber)	Vacuum bagging
Quick release	Mild steel (Hardened)	Hobbing
Column	Mild steel	Turning and grinding
Universal joint	Steel	OEM
Rack and pinion gear	EN 19(Hardened)	Hobbing
Gearbox casing	Aluminium 6082	Vertical milling center
Tie-rods	Mild steel	Turning and tapping

Table -1: Materials selected and Manufacturing process

Fig -7: Final CAD Model of steering system assembly

6. CONCLUSIONS

The steering system fulfills completely the mandatory competition rules to compete with the car, all the objectives like driver comfort, good steering response, Weight reduction and simple assembly are met with this steering system design.

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BIOGRAPHIES

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The Author is currently in the Third year of Bachelors of Mechanical Engineering from the JSPM'S RSCOE Pune, India. Author is interested in Design and analysis of vehicle dynamics and Product design using modelling software's.