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STUDY & DESIGN OF A STEERING MECHANISM FOR AN ALL TERRAIN VEHICLE

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Abstract

A steering mechanism is a collection of components and linkages which allows the vehicle to achieve desired path, either to avoid and obstacle or change direction. In a steering mechanism, linear movement of components and linkages gives angular motion of wheels.Steering mechanism of any All-terrain vehicle helps the driver in obtaining control on the manoeuvrability of the vehicle.Since the steering system is directly in control of the driver, it is very important to take human comfort into consideration while designing the steering mechanism. The effort required by the driver in controlling the vehicle using steering mechanism is an important. This study aims to study and design a steering mechanism for an All-Terrain Vehicle (ATV) in accordance with the rulebook of SAE-BAJA 2016 provided by SAE INDIA. In this paper, we will study different steering mechanisms and out of which is best suited for an All-Terrain Vehicle. After selecting the optimal steering mechanism, we will study and select its various output parameters like turning radius, stability, traction etc. Fixing these values, we will perform various iterations to achieve optimal solution. We will fabricate various parts of steering mechanism based on the optimal values. Considering various attributes such as turning radius, inner & outer steer angle, Scrub radius Castor, Camber, Rack & Pinion is formulated and designed. Based on the result obtained from calculations the design is modified accordingly. Also, other components of steering mechanism like tire rod, universal joint, can also be designed but in this study, we will only design rack & pinion.

Index Terms: **Steering mechanisms, Rack & Pinion, SAE BAJA rulebook, Turning radius, Castor, Camber, ATV**

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I. INTRODUCTION

Vehicle when accelerated needs to be controlled and given certain direction to obtain desire course of path or to avoid obstacles. Steering system is used for controlling the directional characteristic of wheel and attend stability of vehicle.Steering system is the collection of components, linkages, etc. which allows any vehicle (car, motorcycle,) to follow the desired course. The geometry and position of these linkages plays a vital role in stability of vehicle as inhibits the superfluous movement of wheels. For designing efficient steering system one has to consider kinematic of steering system and dynamics of vehicle as well. As we are designing steering mechanism for an ATV (All-terrain vehicle) considering all the rough-and-tumble aspects and in which vehicle will be driven through thus it is necessary to fabricate efficient steering system using all the necessary parameters like turning radius, king-pin inclination, castor, camber etc. Steering system of an ATV needs to be efficient as far as the other parameters like weight, space considerations, rigidity are concerned also taking in consideration the cost of entire system. The efficiency and reliability of gears used in steering mechanism is very important.

II. STEERING MECHANISM

Why do we need steering mechanism?

1)To control the angular motion of the wheels and thus the direction of vehicle motion.

2)To provide the direction stability of the vehicle.

Various steering systems are compared below which clearly states that why rack and pinion is been opted.

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Table 1: Comparison of different steering System

Steering system	Cost	Availability	Weight	Mechanical Advantage	Total
Rack &Pinion	7	9	7	6	29
Recirculating Ball	5	6	6	9	26
Worm & Sector	5	4	5	7	21
Tractor Mechanism	7	8	5	5	25

According to the constrains provided by SAE BAJA there are two types of steering mechanisms optimal for our ATV namely: -

1. Davis Steering Mechanism:

Davis steering mechanism comprises of two turning and two sliding pairs which consequently leads to wear and tear of components. According to geometry Davis Mechanism is the perfect mechanism as compare to the Ackermann.

2. Ackermann Steering Mechanism:

At any angle of steering, the line drawn from all the axis four wheels will coincide at a common point. The track arms are made inclined so that if axles are extended they will meet at longitudinal axis of the car near rear axle. It has only 1 turning pair so wear and tear of gears is less. It is not accurate mathematically except three positions.

Table 2: - Difference between Ackermann & Davis steering mechanism

Sr. No.	Davis Steering	Ackermann Steering
1	Two turning and two sliding pairs	One turning pair
2	100 % perfect mechanism	Partially Correct
3	Wear and tear is more due to sliding and turning pairs	Wear and tear negligible
4	High cost	Low cost

III. AIM AND OBJECTIVE

Study and Design of a steering system according to the constraints provided by SAE BAJA RULEBOOK-2016 for an ATV (All-Terrain Vehicle).

IV. PROBLEM STATEMENT

After considering all the pros and cons of the types of steering systems we concluded that Ackermann steering mechanism is most appropriate option due to its reliability and cost efficient.

As it is an ATV using 100% Ackermann is not suitable so we will optimize to meet our desired constraint for SAE BAJA 2016.

V. DESIGN CONSIDERATIONS

Considering the following objectives, the steering system was designed:

1. Minimize cost.
2. Increase Efficiency.
3. Improve Responsiveness of steering system.
4. Minimize turning radius
5. Develop a new mathematical model to design such Ackermann steering geometry instead of try and error method.
6. Study and design of steering system is according to SAE BAJA RULEBOOK 2016. Design and calculations are made according constraints provided in RULEBOOK.

VI. SCOPE

In this project, the conditions satisfying the parameters like camber, castor, turning radius, traction will be optimised and calculated from Ackermann steering law. Changes in design and calculation will be made after test been performed. Steering will be designed according to the aspects of roll-cage. The mounting points of the steering will be designed. Eventually the steering system will be mounted on vehicle.

VII. DESIGN METHODOLOGIES

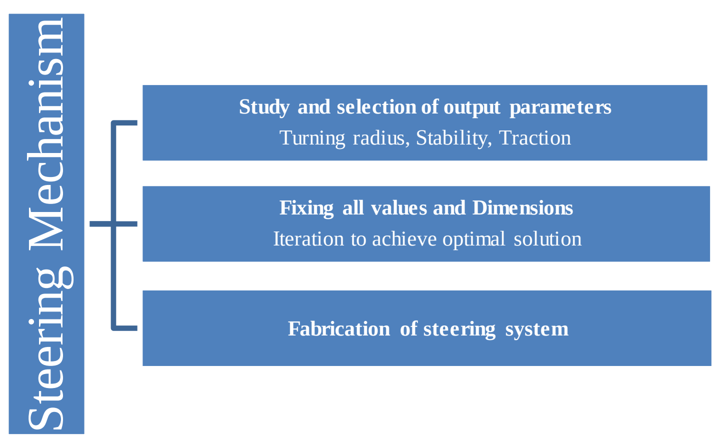

Fig 1: Design Flowchart

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Output parameters of steering: -

1. Turning Radius: - The minimal turning radius of vehicle while taking a turn.

Turning radius$=\frac{\text{Track}}{2}+\frac{Wheelbase}{\sin(\text{average steer angle})}$

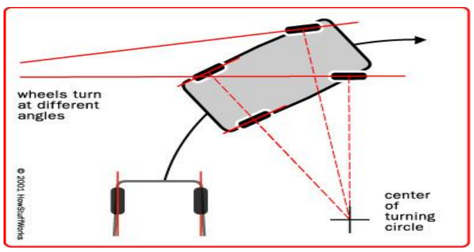

Fig 2: Turning Radius

2. Traction: - The friction between the driving wheel and the surface upon which it moves.Traction is the amount of force applied by wheel on its surface before it slips. The traction of wheel vary from surface to surface; the coefficient of friction is based on pairs of surfaces.

3. Scrub radius: - The distance in front view between kingpin axis and centre of contact of the patch of wheel is known as scrub radius.

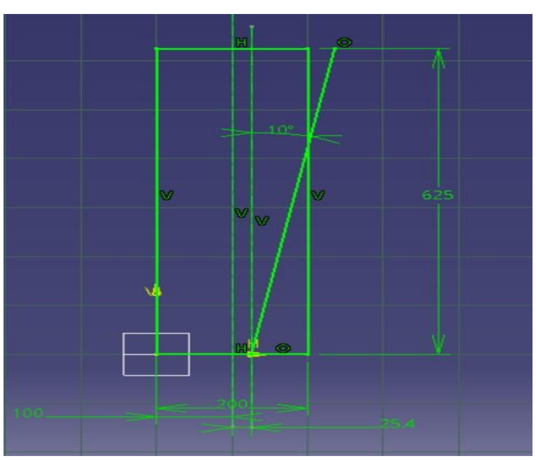

Fig 3: - Scrub Radius

4. Castor: -Castor angle is the angular displacement of the steering axis from the vertical axis of a steered wheel in a car. The traction and turning radius of wheels can optimised by adjusting castor angle of wheels, either zero or positive castor angle. We have chosen zero castor angle. Ensuring the consistency of wheels with each other are optimized for maximum traction and also for enhancing understeer and oversteer as we need them according to geographical conditions.

5. Camber: - In front view, the angle between vertical axis of tyre and vertical axis of vehicle is known as Camber. The turning radius of vehicle or steering wheel rotation can be minimised by opting positive Camber.

6. Toe: - Toe is termed as inclination of tyres either inward or outward from a top down view.Well-manneredtoe is supreme to even tread wear and extended tire life.

   i) Toe-in: - The front wheels are inclined inward in such a way that the distance between front ends slightly less than the back ends. This helps in achieving understeer for the vehicle. This leads oversteering in vehicle.

Fig 4: Oversteer

   ii) Toe-out: - The front wheels are slightly turned out so that the distance between front end is slightly more than back end. This helps in achieving oversteer for the vehicle. This leads to understeering in vehicle.

Fig 5: Understeer

VIII. CALCULATIONS

1) Calculation for steering ratio

$$steering\ ratio = \frac{\square wheel}{\square\ driver} = \frac{\square castor + \square kpi}{\square driver}$$

$\square_{castor}$=F x trail=3000x0.044=133.35Nm

$\square_{kp}$i=F x scrub radius=3000x0.254=76.2 Nm

$\square_{wheel}$== $\sqrt{(\square castor)^2 + (\square kpi)^2}$ = 153.58 N

$\square_{driver}$ = F x Steering wheel radius

= 160x6''=24.384 Nm

Steering ratio= $\frac{153.58}{24.38}$ =6.2983

Steering ratio x FOS = 7

1.2983 x FOS = 7
FOS=1.15

(OR)

Steering ratio=

$$\frac{lock\ to\ lock\ steering\ wheel}{(Inner\ steering\ angle + Outer\ steering\ angle)} = \frac{315}{(Around\ 50)}$$

=6.1789

Lock to lock of steering wheel =315°

Turns= $\frac{315*2}{360}$ = 1.75 turns

7:1 = Steering ratio

7=1; X=45

X=315°

2) Calculations for rack & pinion

Rack Travel= (Circular pitch) x No. of teeth

= ∏ x m x z

= ∏ x $\frac{d}{z}$ x z = ∏ x 25=3.14''

Force on rack = $\frac{\square Driver}{Rod\ of\ pinoin}$

= $\frac{24.384}{(\frac{25}{2})mm}$ = 1920 N

Force on steering wheel = F * □* scrub radius

= $\frac{100}{2}$ x 0.7 x 1''
= 8.89 Nm

Inner ball joint radius = rack length=12''

Outer ball joint radius =Kingpin Length =43''

Length of tie rod =19''

3) Calculation for turning radius

Turning radius= $\frac{Track\ width}{2}$ + $\frac{wheel\ base}{\sin(of\ avg\ steer\ angle)}$

= $\frac{50}{2}$ + $\frac{60}{\sin(45)}$
= 2.706 mm

For Rack and Pinion = $\frac{\square driver}{rod\ of\ pinion}$ =$\frac{24}{\frac{25}{2}}$
=1920 N

1920 x length of steering arm =should be able to overcome $\square_{wheel}$

1920 x l≥ 153.56 Nm

l≈ 3"

Percentage Ackerman = 100 x $\frac{\text{Actual Ackerman}}{\text{Ideal Ackeraman}}$

Ackerman = inner steer angle- outer steer angle

100 % (ideal) = (ideal inside steer angle-ideal outer steer angle)

For ideal Ackerman = inside = 35°
=Outer=23.06°

% Ackermann =

$\tan^{-1}\left(\frac{Wheel\ base}{Turning\ radius + (\frac{Track\ width}{2})}\right)°$

%Ackermann = 100 x ($\frac{30-21}{35-23.06}$) = 75.37 %

Our actual Percent Ackermann is 75.37 %.

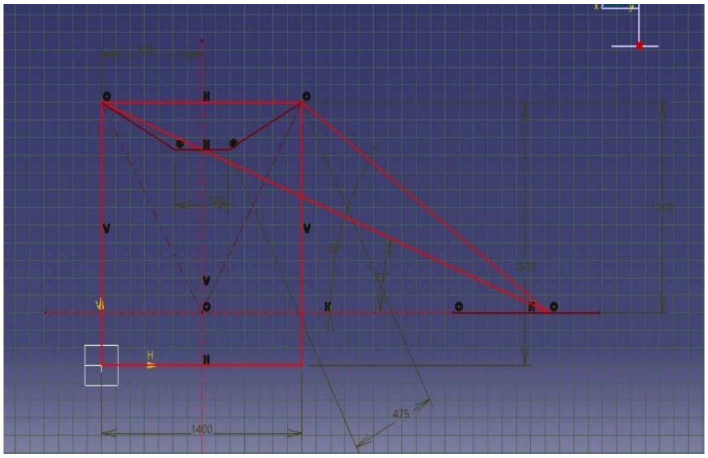

Fig. 6: - 75% Ackermann geometry

IX. DESIGN OF RACK AND PINION

After carrying out certain iterations we finally succeeded in obtaining percentage Ackermann. With the values obtained from calculation we designed for a rack & pinion on Catia V5. The rack & pinion designed on Catia V5 is shown below,

Fig 7: Rack Rod

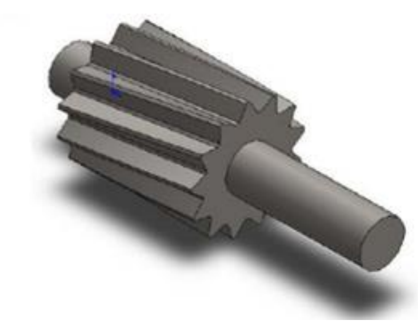

Fig 8: Pinion

X. MATERIAL SELECTION

The material to be used in our steering system should be light in weight and precise in operation. Other parameters to be considered while designing this system are cost, manufacturability and reliability. Precision in steering system should have high manufacturing tolerance and minimal deflection. So, the material we use to manufacture to manufacture rack &pinion is Aluminium alloy. The material used for manufacturing tie rods is Mild Steel.

XI. CONCLUSION

Thus, we have studied all the important parameters related to a steering mechanism and successfully designed our steering mechanism with actual percentage Ackermann=75.37%.

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