DESIGN OF STEERING SYSTEM FOR AN ALL-TERRAIN VEHICLE

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Abstract - *The Steering system is one of the vital subsystems of a vehicle which provides directional control and stability. In this project we are designing a steering system for an All-Terrain Vehicle. An All-Terrain Vehicle (ATV) is a vehicle that can travel on all different terrains. As a result, the steering system is designed for the worst-case scenario, providing maximum directional control, pure rolling motion to the wheel, and the minimum possible turning radius. The main aim of this paper is to design a efficient steering system for an ATV.*

Key Words: ATV, Steering System, Ackermann geometry, Rack and Pinion, Design

1.INTRODUCTION

The steering system is a set of assembled components that guides the vehicle to follow a desired course based on the driver's input. The goal of the steering system is to provide directional control for the vehicle, to reduce steering effort and offer proper road response to the driver.

The Ackerman steering system is designed using a four-bar linkage mechanism in which several linkages move relative to one another and direct the vehicle in a specific direction. This system is useful in sharp corners since it reduces steering effort and facilitates maneuverability.

In comparison to other steering mechanisms, the rack and pinion mechanism is ideal due to the obvious benefits of simple design, ease of manufacturing, significantly reduced space requirements, and cost-effectiveness.

The pinion of a rack and pinion system meshes with the pinion, which is fastened to the end of the steering shaft. The pinion is rotated by rotating the steering wheel. The movement of rack is responsible for turning of wheels through steering linkages.

2. LITERATURE REVIEW

The following literature survey gives a preview glimpse of our work in this research related to design of steering system in an ATV.

Mohan poojari et al. [1]: Designed a 2-D Turning radius mechanism by using Catia V5R21 considering the acquired basic parameter rack length steering arm length and other parameters are changed to obtain different turning radius and Ackermann percentage values.

William F. Milliken and Douglas L. Milliken [2]: In the book of Race Car Vehicle dynamics It is shown that if the wheel steers automatically when it turns over a bump or droop or when the vehicle rolls in a turn the vehicle will travel in a path that driver did not select. So it is good to keep zero bump steer.

Akshay Pawar and Suraj Zambare [3]: Wheelbase and Track Width are decided considering the suspension geometry, handling and stability of the vehicle. Kingpin offset was decided by considering the wheel assembly and castor angle selected so that it gives straight line stability and optimum self-returning action for better handling. Position of rack is chosen by considering pedal position and to avoid significant amounts of bump steer.

Shylaen S Keshwani and A. M. Surendra Kumar [4]: To make calculation simpler a C-Program was coded which calculates various steering values needed such as Ackermann angle, Tie Rod Length, Steering Ratio etc. This program was simulated under different Ackermann angle, and it was inferred that when the Ackermann angle increases the outer wheel turns lesser, which gives the better steering response, and input variability increases hence it gives smooth driving.

Nitish Malik et al [5]: Increased the diameter of steering wheel to reduce the steering effort because the driver effort to rotate the steer has been increased upon reducing the steering gear ratio.

Amit Kumar Shakya et al. [6]: To minimize the bump steer tie rod must be parallel to Suspension A-Arms so that during bump the Instantaneous center of the tie rod meets the instantaneous center of the A-Arms at infinity. In this manner, the arc travelled by the tie rods and the arms were equidistant to each other during suspension travel, and no force was generated along the rack to produce bump steer.

Kshitij N Sable et al. [7]: The calculated values were validated using lotus shark software to check the proper functioning of suspension systems and then the designing of components were done in CAD Software CATIA V5 R21. All the components are analysed to the real world using Finite Element Analysis

Prashant L Agrawal et al. [8]: It was mentioned that the length of the steering rack is directly proportional to the angle of the steering wheel and inversely proportional to the average turning radius of the vehicle.

Sandeep Chaudhary et al. [9]: While a vehicle taking a turn the outer wheel travels more distance than the inner wheel i.e., inner wheel makes higher angle than the outer wheel. So Higher the steering angle smaller will be the turning radius.

3. MATERIAL AND METHODS

Element	C	Si	Mn	P	S	Cr	Mo	Ni
Content (%)	0.10-0.20	0.10-0.35	0.50-1.00	0.040 (Max)	0.040 (Max)	0.75-1.25	0.08-0.15	1.00-1.50

Table -1: Chemical Composition of EN-353

Mechanical Properties	Density (gm/cm^3)	Young's Modulus (Gpa)	Poisson's Ratio	Yield Strength (Mpa)	Compression strength (Mpa)	Ultimate Tensile strength (Mpa)
Value	8.08	190	0.26	440	550	550

Table -2: Mechanical Properties of EN-353

Since EN353 has good ductility and fatigue strength we use it for rack and pinion.

4. DESIGN OF STEERING SYSTEM

4.1 Requirements of Steering system

Steering system should be designed in such a manner so that

- It should be accurate and easy to handle,
- Steering effort should be minimum,
- Road shocks should not be transferred to driver and
- It should provide pure rolling motion to wheel

4.2 Design Methodology

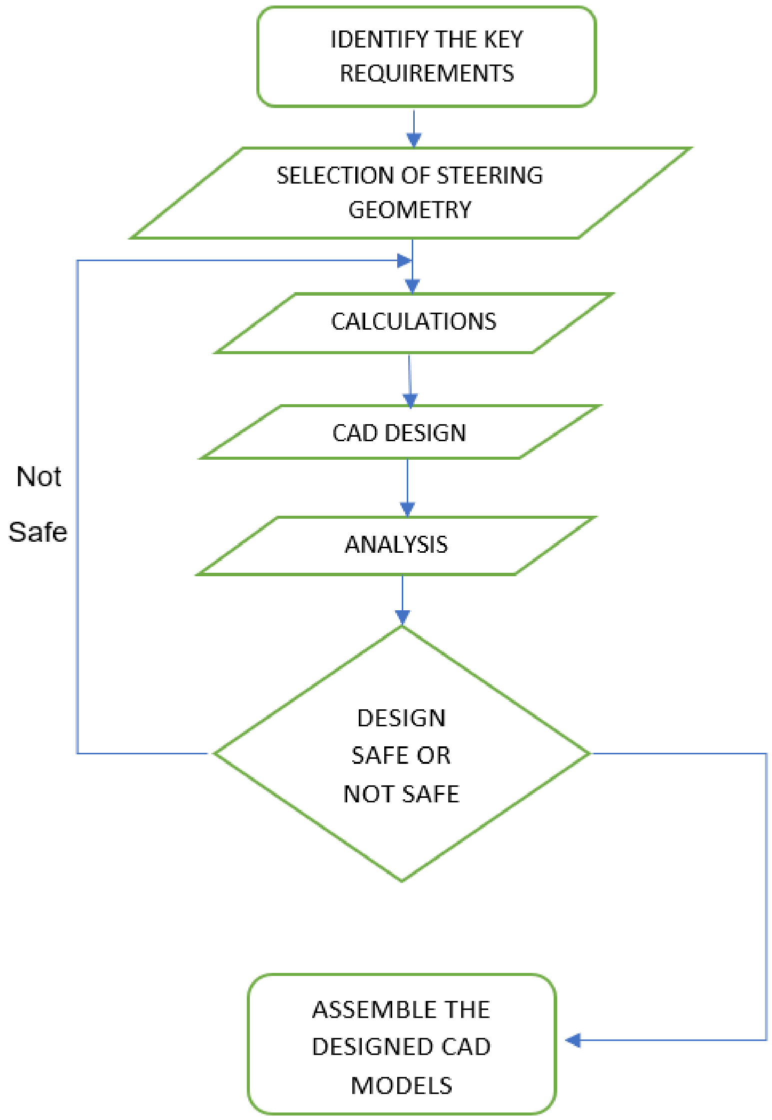

Fig -1: Design Methodology

4.3 Selection of Steering Geometry

Traction is an important factor in off-road racing as compared to speed. We choose Ackermann steering geometry since it gives high stability at lower speed. Because of the terrain, this geometry is suitable for BAJA vehicles with a speed limit of 60 kmph.

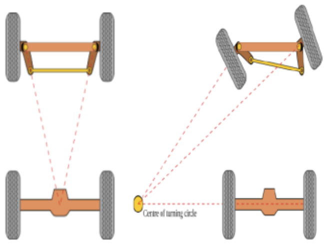

Fig - 2: Schematic Diagram of Ackermann Steering [3]

According to the Ackermann principle, the extended axes of the steering arm should meet at the centre of the rear axle. When a vehicle is turning, the condition of perfect rolling is reached when the extended axis of the front wheels and the rear axis meet at a point. This point is called instantaneous centre of the vehicle. The inner wheel deflects more than the outer wheel while a vehicle travels along a curved path to prevent skidding while cornering.

4.4 Steering Design Parameters

PARAMETERS	DIMENSIONS
Track Width (mm)	1219.2
Wheelbase (mm)	1320.8
Lock to Lock	1.25
Inner Wheel Angle (Deg.)	48
Distance between Kingpin Center – Center (mm)	1122.68
Ground Clearance (in)	12

Table -3: Initial Parameters for steering design calculations

4.4 Steering Design Calculations

Ackermann angle

tan α = king pin – king pin centre distance /2 x(Wheelbase)

$\alpha = \tan^{-1}$ (1122.68/2x52x25.4)

α = 23.03°θ

Max inner wheel angle, Assume, θ = 48°

By Ackermann condition

Cot (Φ)- cot (θ) = Track width/wheelbase

(Φ) = 28.74° So = 29° (Max outer wheel angle)

Turning radius of the wheel

Turning Radius of front inner wheel, Ri = wheelbase /Sin (θ) - (Track width -K. k)/2

Turning Radius of front outer wheel, Ro = Wheelbase/ Sin (θ) - (Track width -k. K)/2

Ri = 1729.50 mm, Ro = 2698.59 mm

Turning Radius (Vehicle)

R = (Ri + Ro) /2 =2.2m

Ackermann percentage

Ackerman % = Si/ Ackermanx100

Ackerman = $\tan^{-1}$ (Wheelbase/(tan(Φ)*Trackwidth))

Ackerman percentage = 101% (>100%) over steer

(Assume lock to lock to be 1.25 revolution)

Lock to lock = Steering Wheel angle /360°

Steering wheel angle = 1.25 x 360°= 450°

The steering wheel must be rotated about 450°

Steering Ratio

Steering Ratio = steering wheel angle (Full lock on one side)/Inner wheel angle

= 225/48° =5

Steering ratio = 5:1

Rack travel

Steering ratio = steering wheel travel (full rotation)/Rack travel

5= (2 *π*(5*25.4) *540)/360/Rack travel

∴Rack travel = 188.435mm (full)

On one side, rack travel = 94.2 mm

∴Diameter of steering wheel

Steering ratio = steering wheel circumference /pinion circumferences (or)

Radius of steering wheel /Radius of pinion

5= 5*25.4/r

r=24 mm

d= 48 mm(pinion)

No of teeth in pinion

Assume module = 2*m= D/T ∴T=D/m= 48/2= 24

Gear ratio = 540°/ 360°= 1.25

Gear ratio= Number of teeth in rack/ Number of teeth in pinion 1.25= N/18

No of teeth in rack = 30

Import the Calculated values in Lotus shark software to check the suspension character.

4.5 Steering Geometry Setup

After getting the system aims clear, the steering iterations were done in Lotus Shark software. Some of the predetermined parameters are listed in the above table.

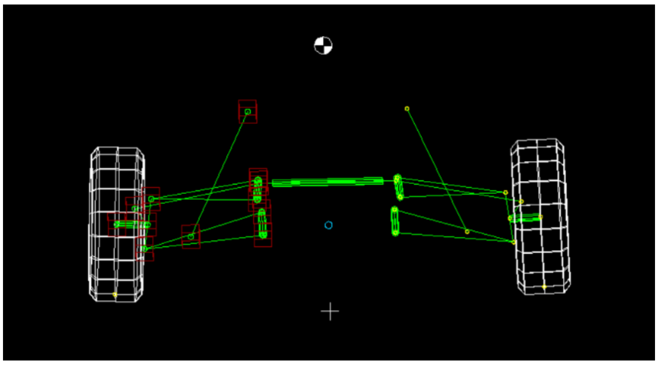

Fig -3: Lotus shark Interface

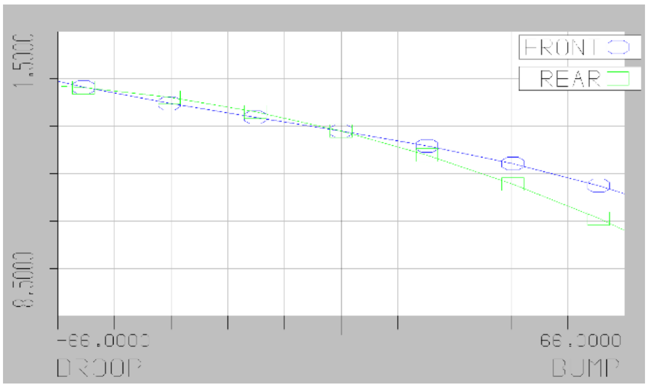

Fig -4: Wheel Travel in Bum and Droop

Final Design Parameters

After several iterations in Lotus shark software final parameters for designing the steering system were mentioned below.

PARAMETERS	DIMENSIONS
STEERING MECHANISM	RACK AND PINION
ACKERMANN ANGLE	23.03
STEERING ARM LENGTH	90mm
INNER WHEEL LOCK ANGLE	48Deg
OUTER WHEEL LOCK ANGLE	29Deg
STEERING RATIO	5:1
ACKERMANN PERCENTAGE	101%
TYPE OF STEERING	Oversteering
STEERING ARM LENGTH	91mm

Table -4: Final Design Parameters

Since Ackermann Percentage greater than 100% The type of steering will be Oversteering. Oversteer is a tendency for cars to turn sharper than the driver intended, helping the tires grip sharp corners.

4.6 CAD Modelling

We have designed complete assembly of rack and pinion in SOLIDWORKS 2021.

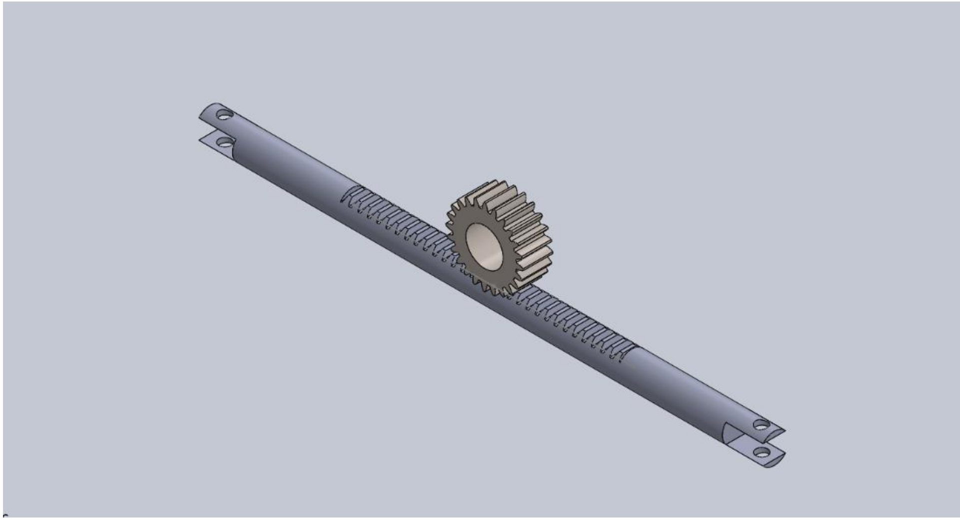

Fig -5: Rack and Pinion

4.7 CAE Analysis

The Designs were validated in ANSYS 17.2.

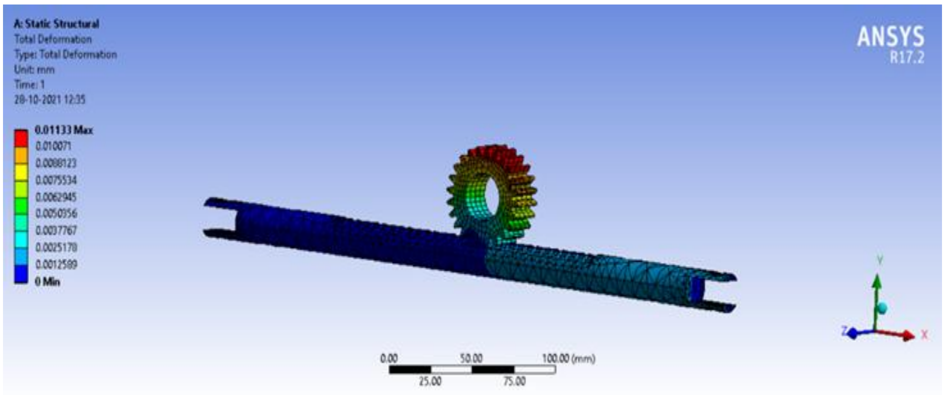

Fig -6: Deformation of Rack and Pinion

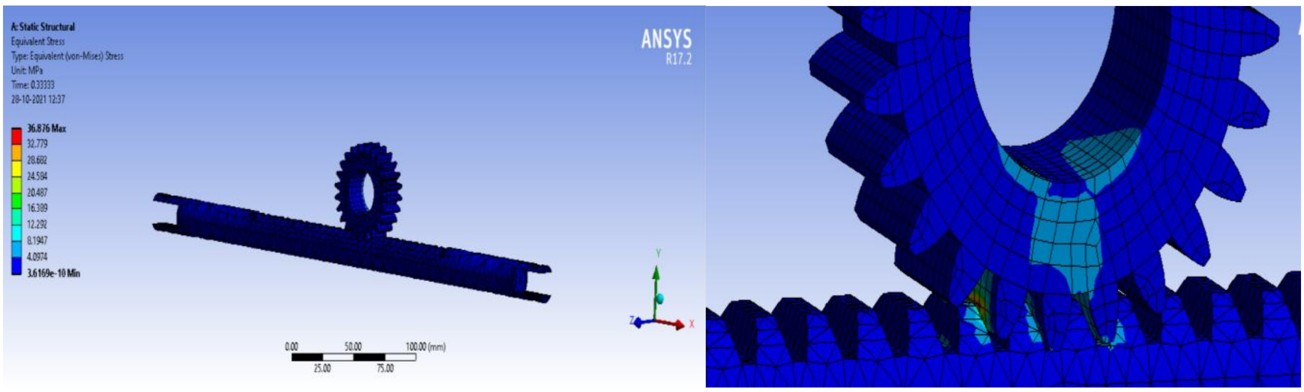

Fig -7: Equivalent Stress on Rack and Pinion

Rack Pinion

MAXIMUM DEFORMATION =0.01133 mm

MAXIMUM STRESS = 36.876 Mpa

Factor of safety = 8.1

The design is Safe.

Fig - 8: Assembling of CAD Models

5. CONCLUSION

The steering system plays an important role in the overall performance of All terrain vehicles. This research paper concluded by presenting a complete design methodology as well as resulting optimal designs that can be manufactured for the given real-time condition. It can be used in off- roading vehicles. The following conclusions are observed:

The steering has been designed to produce minimum turning radius of 2.2m with 101 percentage. A steering ratio of 5:1 is achieved along with low steering effort.

6. REFERENCES

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BIOGRAPHIES

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