Journal of Analysis and Computation (JAC)
(An International Peer Reviewed Journal), www.ijaconline.com, ISSN 0973-2861
Volume XVI, Issue IV, Jan-June 2022

DESIGN & ANALYSIS OF STEERING SYSTEM FOR CAMPUS DRIVE ELECTRIC VEHICLE

Pratima Nikam[1], Mandar Kadbane[1], Raviraj Nigade[1], Anant Buddhisagar[1], Ganesh Eknath Kondhalkar[2]

[1] Graduate Scholar, Mechanical Engineering, ABMSP's Anantrao Pawar College of Engineering & Research, Pune, Maharashtra, India

[2]Assistant Professor, Mechanical Engineering ABMSP's Anantrao Pawar College of Engineering & Research, Pune, Maharashtra, India

---

ABSTRACT-

This research paper aims for making prototype, steering system for six seater campus drive vehicle. Designs are made according to the availability of components in the market. The decreasing fuel resource in the world makes it a necessary to search for renewable options. This vehicle is a four-wheeler and drive by BLDC motor and also driven by a battery which charged with electricity. Used rack and pinion steering system to turn the vehicle. Rack and pinion steering system selected because of its simplicity, less effort and less cost. Our project requires engineering skills. The main requirement is that the steering should be precise, with no play. In addition, the steering system should be smooth, compact and light. Steering system is used to turn vehicle in any direction i.e. right or left. The main of the steering system is to providing direction stability while moving on straight it must also provide the driver with a perfect feel for the road surface and help the wheels return to the straight-ahead position. Among two basic steering mechanisms i.e. rack and pinion and recirculating ball mechanism, rack and pinon method was chosen considering various parameters such as availability, widely used and cost .In the rack and pinion system, a pinion gear is attached to the steering shaft, i.e. turning the steering wheel turns the pinion gear which then moves the rack

Keywords: Design and calculations of steering system, Rack and Pinion Mechanism

---

INTRODUCTION

The steering system allows the driver to guide the vehicle along the road and turn left or right. The primary function of the steering system is to negotiate a turn to achieve angular motion of the front wheels and to provide directional stability of the vehicle when going straight ahead. Also to facilitate straight ahead recovery after completing a turn. Requirements of a good steering is easy to handle, Provide directional ability, multiply the turning effort applied on the steering wheel by the driver & Irreversible to certain degree, so that the shocks of the road surface encountered by the wheels are not transmitted to driver's hands. The steering wheel rotates the steering column. The steering gear box is fitted to the end of this column. Therefore, when the wheel is rotated, the cross shaft in the gear box oscillates. The cross shaft is connected to the drop arm. This arm is linked by means of a drag link to the steering arms. The steering arms on both wheels are connected by the tie rods to the drag link .When the steering wheel is operated the knuckle moving the wheels to the right or left. The ends of the tie rod and steering knuckle are connected to each other. One end of the drag link is connected to the tie rod. The other end is connected to the end of the drop arm. A ball and a socket joint gives the required movement to the joints between the tie rod, drag link and drop arm. When the vehicle is moving, the drop arm develops vibration. Shock springs are used in ball and socket system to absorb this vibration.

II. METHODOLOGY

LITERATURE REVIEW Gathered many research papers which are relevant to this topic
ANALYSIS Analysis of reference vehicle
SELECTION OF COMPONENTS Steering wheel, Steering shaft, Universal joint, Pinion, Rack, etc.
MARKET SURVEY Market survey for the components used
CALCULATION Making calculations with the reference of research papers and based on the market survey
DESIGN Design of cad model of steering from calculation and assembly
FEA ANALYSIS Calculate the values of total deformation & von-mises stress

III. WORKING PRINCIPLE

The steering wheel rotates the steering column. The steering gear box is fitted to the end of this column. Therefore, when the wheel is rotated, the cross shaft in the gear box oscillates. The cross shaft is connected to the drop arm. This arm is linked by means of a drag link to the steering arms. The steering arms on both wheels are connected by the tie rods to the drag link .When the steering wheel is operated the knuckle moving the wheels to the right or left. The ends of the tie rod and steering knuckle are connected to each other. One end of the drag link is connected to the tie rod. The other end is connected to the end of the drop arm. A ball and a socket joint gives the required movement to the joints between the tie rod, drag link and drop arm. When the vehicle is moving, the drop arm develops vibration. Shock springs are used in ball and socket system to absorb this vibration.

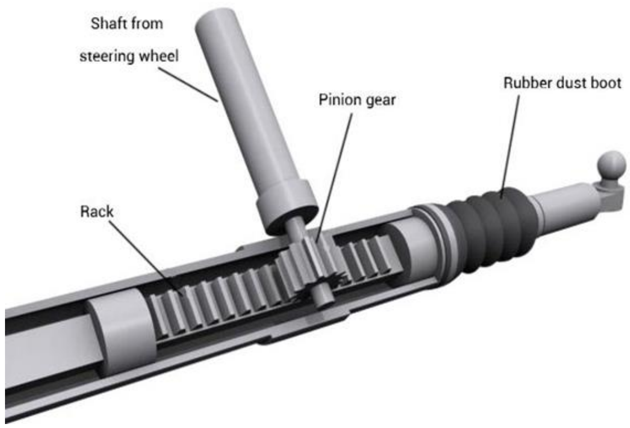

Fig 1. Working Of Rack And Pinion Mechanism

IV. DESIGN CALCUIATIONS

A) Selection of Material

For the designing of any machine part, selection of material is the first step. Improper material selection can lead to its failure. Material selection process considers the factors such as strength, hardness, cost, and availability To avoid above failure modes and considering the above mentioned material selection factors the material for gear is chosen to be SAE 1018.It has generally good mechanical properties .The mechanical properties of mild steel are given below in table 1.

Table 1: Mechanical Properties OF M.S.SAE1018

Sr. No	Property	Value
1	Density	7850 kg/m3
2	Melting Point	1370 ^{0}C
3	Yield Strength	240 Map
4	Tensile Strength	370 Map
5	Modulus of Strength	205 Gap
6	Poisson's Ratio	0.33
7	Brinell Hardness	126 BHN

Table: 2 Ackerman geometry with values

Geometry	**Ackerman Geometry**
Steering type	Rack and Pinion
Wheelbase (b)	2900
Track width (c)	1900
Inner Wheel angle (ϴ)	30^{0}
Outer Wheel angle (ϕ)	22.36^{0}
Ackerman angle (ά)	30^{0}
Inner turning radius	6.07 m
Outer turning radius	7.84 m
Steering Ratio	2.77

Calculations made by considering Ackerman's mechanism. Table 2 shows important parameters required to design steering system.

Wheelbase (b) =2900mm

Track width (a) =1900mm

Distance between kingpin (c) = 1700mm

Inner wheel angle (ϴ) = 30^{0}

Outer Wheel angle (Ø) = 22.36^{0}

Now, assume the outer wheel turning radius make angle (ϕ)

Outer Wheel angle (ϕ)=22.36^{0}

From equation of correct steering angle we calculate another angle i.e. Inner Wheel angle (ϴ)

Cot (ϕ)-cot (ϴ) = c/b

Cot (ϴ) = 1.77

ϴ = 30

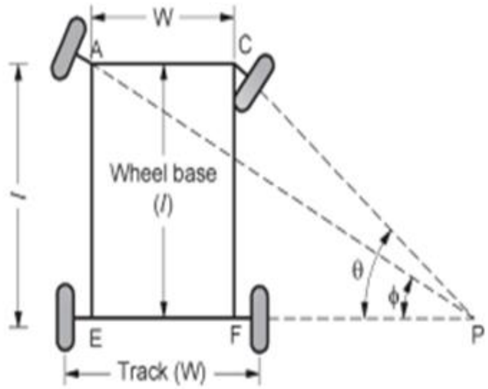

Fig 2. Ackerman Steering Geometry

Ackerman angle (α) =$\tan^{-1}$(c/b) =30^0

Inner turning radius (Rin) = b/sin (Ɵ)-(a-c/2) = 6.07m

Outer turning radius (Rout) =b/sin (Ø) + (a-c/2) = 7.84m

Steering Ratio = number of teeth on rack divided by / (number of teeth on pinion gear)

Steering ratio= (50/18) = 2.777

B) Design pinion:

Material for rack and pinion = Mild Steel ……… (I.S. specifications)

Minimum No. of teeth for pinion

Zp=2/$\sin^2$ (ϕ)

=17.09 approx. 18

Module (m) =2 ………As per Indian standard

For 20° full Depth involute system (outer wheel angle=20°)

Addendum (a) = 1×m = 2mm

Dedendum (d) =1.157× Module = 1.157x2 =2.314mm ………As per Indian standard

Pitch circle diameter (D) = Module x ZP = 36mm

Addendum circle diameter (Aa) = M× (Z+2) = 2x (18x2) =40mm

Dedendum circle diameter (Da) = M× (Z-2.5) =2x (18-2.5) =31mm

Clearance (c) = 0.157×M = 0.157x 2= 0.314 mm ………As per Indian standard

Total depth = (a + d) = (2+2.314) = 4.314mm

Working depth = (Total Depth – Clearance) = (4.314-0.314) = 4mm

Tooth thickness = 1.5708×M = 3.14mm ………As per Indian standard

Circular pitch (Pc) = (л x m) = (л x [D/Zp]) = (3.14× [36/18]) =6.28mm

Diametral pitch (Pd) =ZP/D= (3.14)/=0.5

Tooth space = (Pc-Tooth Thickness) = (6.283-2.314) =3.9691mm

Backlash = (Tooth Space-Tooth Thickness) = (3.9691-2.314) = 1.655mm

Gear ratio= zp / zr =18/50=0.36

Diametral pitch (Pd) =ZP/D= (3.14)/=0.5

C). Dimensions of Rack

Rack shaft length = 15 inch = 381 mm

No. of teeth on rack = 50

Rack eye to eye length = 14 inch = 355.6 mm

Rack center lock = 3.5 inch = 88.9 mm

Rack tooth thickness = 3.25 mm

Rack pitch = 6.5 mm.

Addendum and dedendum = 2 mm.

Clearance = 0.5 mm.

Pinion Radius = 0.78 inch = 20 mm ……….. As per standard rack size.)

Steering shaft length = 507 mm.

Steering shaft diameter = 20 mm. (pinion to column joint)

Torque on Pinion

$$T = W \times u \times \frac{\sqrt{B2}}{8} + E2$$

Where,

W = axle weight = 8Kg.

u = 0.7

E = king pin offset. = 55 mm. = 2.1 inch

B = width of tire = 7 inch

$28.8x\ 10^3$ N.mm

Torque on pinion

T = 28.8×10ˆ3 N.mm

T = (T×Zr/Zp)/D = {28.8x [50/18]}/D

= 12×10^3 N.mm

Wear Strength

(Sw) = b*Q*d’p*K

Where,

b = Face width of gear …… (Assume 10mm.)

Q = Gear ratio factor = (2Zr) / (Zr+Zp) =1.47

K = Material constant (250)

d'p = pitch circle diameter of pinion (36 mm)

Sw = b×Q×d'p×K = 10×1.47×36×250 = 132.3 ×10ˆ3N

V. CAD Design

Cad modeling of steering system is done using catia design software. Design of rack and pinion on the basics of the above calculations. Design the parts like steering wheel, steering rod, universal joints, rack and pinion and covering box. Cad part design of rack and pinion are show in fig (3&4) and assembly of parts are shown in fig (5) final cad model of steering system in fig (5)

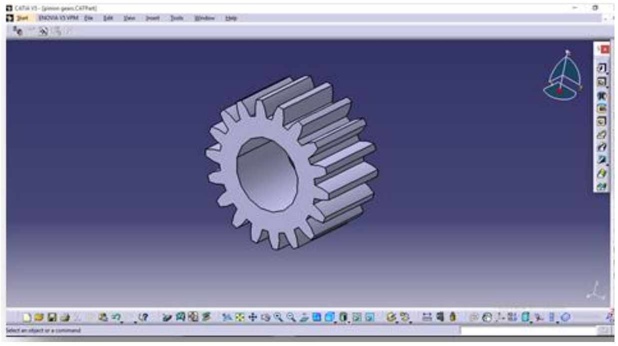

Fig. 3: CAD Model of pinion

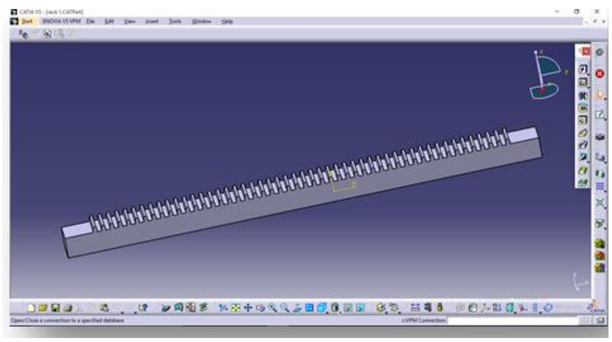

Fig. 4 : CAD Model of Rack

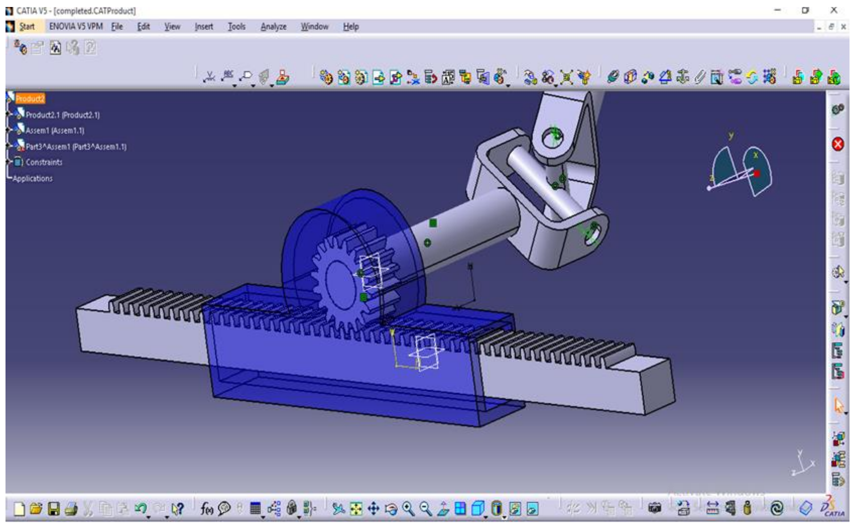

Fig. 5: CAD Model of Rack and pinion Assembly

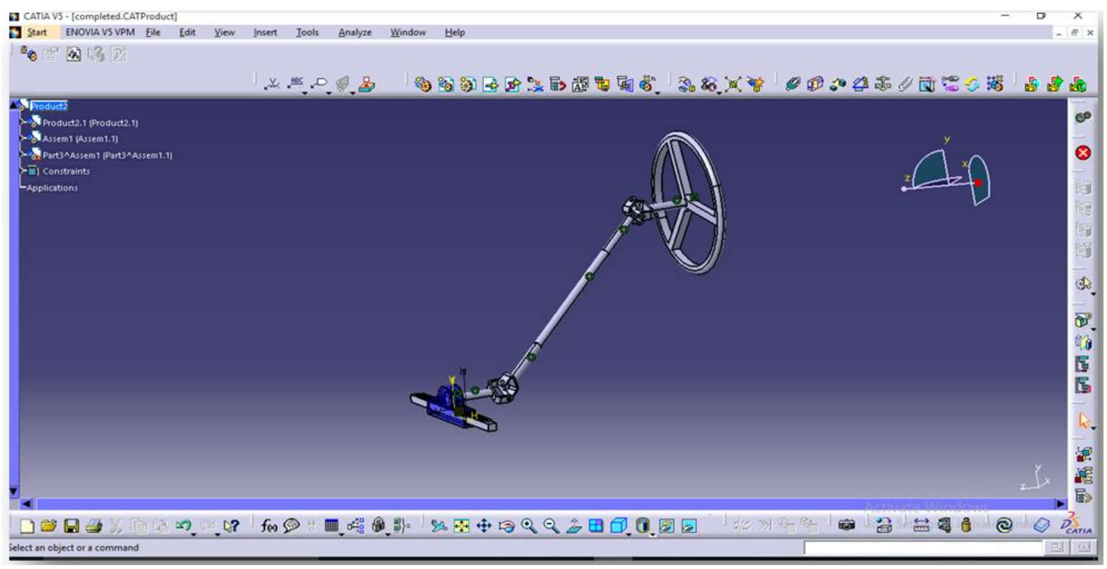

Fig. 6: CAD Model of steering Assembly

VI. ANALYSIS OF STEERING SYSTEM

A) Analysis of Rack

It has been assumed that if stress is applied on rack then it cannot brake but we apply 1600 N force because this is effort required to rotates rack as well as pinion so considering this force carried out analysis of rack as shown in fig

b) Analysis of pinion

Journal of Analysis and Computation (JAC)
(An International Peer Reviewed Journal), www.ijaconline.com, ISSN 0973-2861
Volume XVI, Issue IV, Jan-June 2022

It has been assumed that we are applying same force of 1600 N because it has same material as that of rack now considering this force analysis of pinion is carried out as shown in fig and obtained result show in below table 4

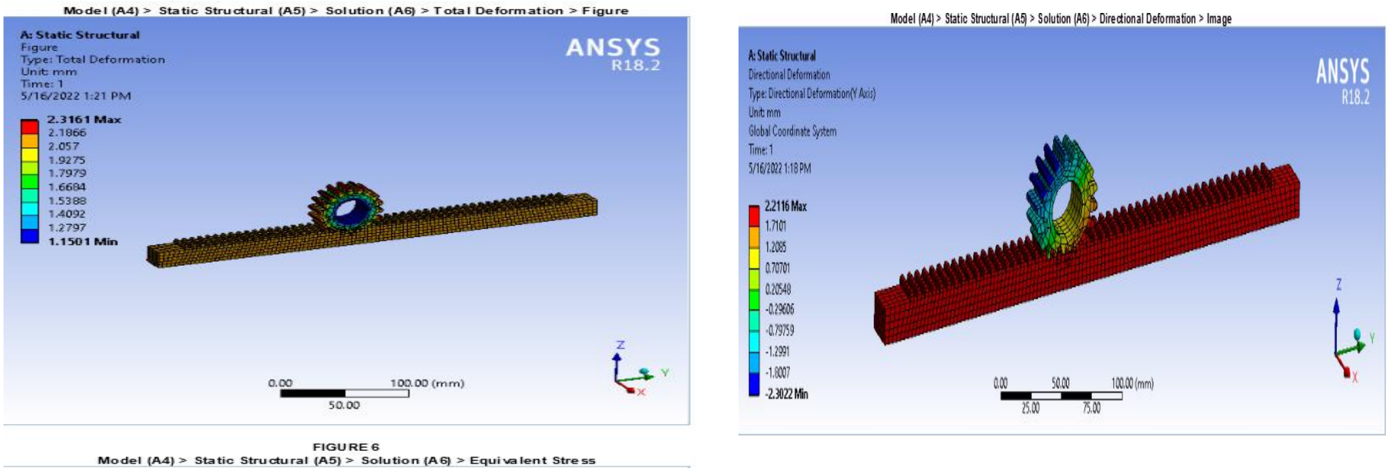

Fig. 7: Analysis of Rack and Pinion (Total deformation & Y Axis deformation)

Table 3 Result of analysis of pinion

Force Applied	1600 N
Max. Deformation (Y Direction)	2.2116 mm
Max. Total Deformation	2.3161 mm

VII. CONCLUSION

Compare values theoretically and numerical (FEA/Ansys), can conclude that deformation produced will be negligible and it can sustain at above mentioned stress. So design is safe the manual rack and pinion steering system not used in heavy weight vehicle due to high axel load but it is simple in design and easy to manufacturing therefore it is commonly used in light vehicles

REFERANCE

[1] Prof. Rahul R. Patil , Mr. Saurabh Pandurang Mahind, Mr. Nikhil Ravindra Bhosale, Design & Analysis of Steering System for Solar Vehicle*, International Journal of Engineering Research & Technology (IJERT) ,ISSN: 2278-0181 Vol. 9 Issue 06, June-2020

[2] Hammad Khurshid, Md Hassaan, Mansha Alam , Design and Analysis of a Steering System for a Formula Student Electric Vehicle , International Research Journal of Engineering and Technology (IRJET) , Volume: 08, Issue: 11, e-ISSN: 2395-0056
p-ISSN: 2395-0072 , Nov 2021

[3] Prof. Sunil Kumar, Amit Kumar Shakya, Harshit Mishra, Design Methodology of Steering System for All-TVehicles, International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056 Volume: 04 , Issue: 05 , May -2017

[4] Omkar Diliprao Suryavanshi, Prathmesh Prasad Sathe , Mahesh Ashokrao Takey, DESIGNING OF THE RACK AND PINION GEARBOX FOR ALL TERRAIN VEHICLE FOR THE COMPETITION BAJA SAE INDIA AND ENDURO STUDENT INDIA , International Journal of Research in Engineering and Technology eISSN: 2319-1163 , pISSN: 2321-7308, Volume: 06 Issue: 09 , Sep-2017

[5] Aaksh Patel, Nandan Bhatt , Mayur Bapu Rawade , Design Methodology and Manufacturing of Rack and Pinion for All Terrain Vehicle , International Journal of Engineering Research & Technology (IJERT) Vol. 8 Issue 06, June-2019

[6] Mr.Vishal Chahare , Miss. Indira Mhaisne, Dnyaneshwar Dongre, An Overview on Future Electric Steering System: A Project Approach , IRJET , e-ISSN: 2395-0056 Volume: 04 Issue: 07 , July -2017

[7] Janardan Prasad Kesari , Yash Sharma, Chahat Goel, Opportunities and Scope for Electric Vehicles in India International Journal of Mechanical Engineering (SSRG-IJME) – Volume 6 Issue 5–May 2019 ISSN: 2348 – 8360

[8] Mohammad Aadil Shaikh , Design of an Electric Golf Cart with Batteries & Solar Panel for 6 Seat Capacity , international Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 06 Issue: 2 | Feb 2019

[9] Sadjyot Biswal, Aravind Prasanth, M S Dhiraj Sakhamuri and Shaurya Selhi, Member, IAENG , Design and Optimization of the Steering System of a Formula SAE Car Using Solidworks and Lotus Shark , World Congress on Engineering 2016 Vol II , WCE 2016, June 29 - July 1, 2016, London, U.K.

[10] Ashish R. Pawar, Topology Optimization of Front Leaf Spring Mounting Bracket, International Journal of Science & Engineering Development Research (IJSDR), ISSN 2455- 2631, 2018

[11] Ashish R. Pawar, OPTIMIZATION OF POWER LIFT GATE SPINDLE & SOCKET ASSEMBLY, Journal of Analysis and Computation (JAC), ISSN 0973-2864, 2020

[12] Ashish R. Pawar, INVESTIGATE OPTIMUM SHAPE OF CRASH BOX ANALYSIS EXPERIMENTALLY AND NUMERICALLY ON GEOMETRY ASPECT, Journal of Analysis and Computation (JAC), ISSN 0973-2864, 2020