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Design and Manufacturing of Steering System in an Off Road Vehicle

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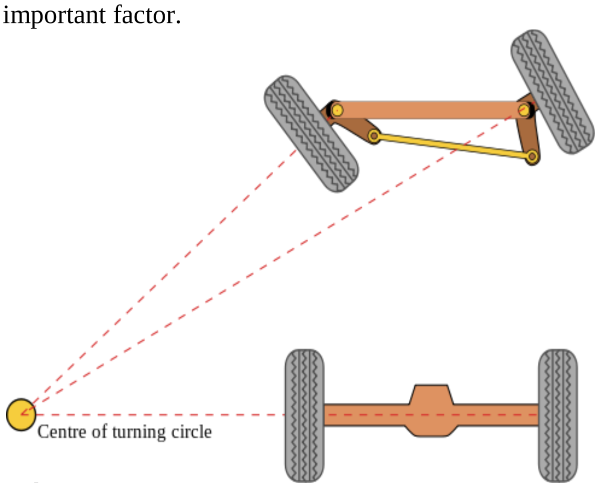
Abstract:
The main objective of this paper designing of the steering system of an off road vehicle. The steering system is the most vital element in any automobile. It helps the driver in obtaining complete control on the maneuvering of the vehicle. Since the steering system is directly operated by the driver it is essential to take human comfort into consideration while designing the steering. The effort required by the driver in handling the steering is an important factor. The steering system is in direct contact with the tires hence it is subjected to extensive forces. Hence it is imperative that the design is tested for failure under such conditions. We have successfully done our steering mechanism in the off road vehicle by the Lotus Suspension Analyzer by obtaining values from the various calculations we performed.

Keywords: Ackerman Principle, Steering Geometry, Rack and Pinion, Design, Manufacturing, Lotus Suspension.

1. INTRODUCTION

The design of steering system has effect on the directional response behaviour of a motor vehicle that is not fully appreciated. The function of steering is to steer front wheel with respect to driver command input in order to provide overall directional control of the vehicle. The steering System plays an important role for the vehicle as it is the "interface" between the driver and the vehicle. The driver turns the steering wheel which will rotate the steering column and give further movement in the steering rack. The motion is then transmitted to the wheels by the tie rods. The design and type of the steering rack depends on the system chosen. The steering systems used are divided into power assisted and manual steering systems, each designed to help the driver to turn easily for optimal performance with different configuration of the vehicle. Since the steering system is directly operated by the driver it is essential to take human comfort into consideration while designing the steering. The effort required by the driver in handling the steering is an important factor.



Ackermann steering geometry is a geometric arrangement of linkages in the steering of a car or other vehicle designed to solve the problem of wheels on the inside and outside of a turn needing to trace out circles of different radii. The intention of Ackermann geometry is to avoid the need for tires to slip sideways when following the path around a curve.

2. OBJECTIVE AND SCOPE

- To design such a light weight steering system which will also reduce the overall weight of vehicle.
- To minimize the turning radius, so that the vehicle can take turn in minimum required space.
- To provide better safety to the Driver.
- To provide more comfort to Driver.
- To increase the strength of rack & pinion.
- To maintain the better steering ratio.

3. DESIGN AND MANUFACTURING

The function of steering system is to steer the front wheels in response to driver command inputs in order to provide overall directional control of vehicle. Design steps involved:
1. Identify vehicle requirement
2. Geometry set up
3. Geometry validation
4. Designing of mechanism
5. Virtual prototyping and analysis of system using CAD and FEA software

1. Identify Vehicle Requirement:

The first step is to identify the system requirements. since objective of our project is to design an efficient steering system for ATV which is going to be a part of the prestigious event called Enduro Student India. The vehicle chassis was designed according to the rule book of SAE INternational-2017, and following parameters were finalized based on driver safety and comfort ability:

- front track width: 46"
- rear track width : 48"
- wheel base (l): 59.5"

Using these basic parameters we started our designing.

3. Geometry Setup:

The geometry setup was performed graphically and it is according to Reverse Ackerman's steering geometry It is the most important step of designing because steering geometry actually decides the maneuverability of vehicle during different driving conditions like bump, jounce and cornering etc. A suspension system also has significant effect on steering ability of vehicle so, a combined efforts in suspension geometry and steering geometry were taken in order to design efficient system. A steering i.e. a four bar linkage. LOTUS software was used for simulation. Following figure shows the graphical validation of geometry:

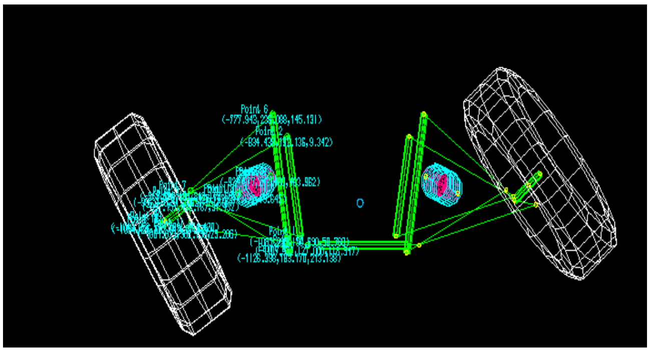
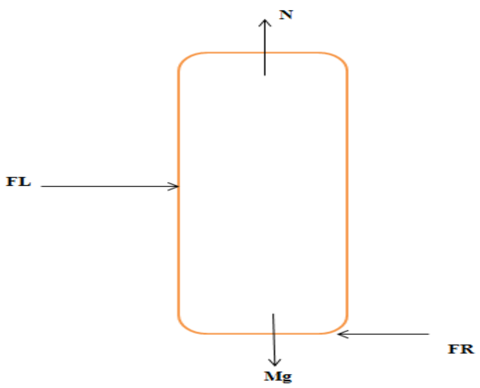


Figure.2. LOTUS Geometry

Parameter	Value
Track width	46”
Wheel Base	59”
Steering Arm Length	325mm
Ackermann angle	25.5°

3. Design of Mechanism

We are using rack and pinion mechanism because of oblivious advantages of reduced complexity, ease of construction and less space requirement compare to other steering mechanisms. The analytical steps involved in designing if rack and pinion system is as follow:



F.V of Wheel

By Columbus law: Normal reaction is directly proportional to frictional force.

$\sum Y=0$

Hence FL-FR=0

FL=FR

$\sum Z=0$

Mg=N

N= weight of front single wheel

Total mass of vehicle is = 270 kg

For 60:40 weight distribution

270x40%=108 Kg

Mass on front wheels= 108 kg

For single wheel =54kg

Vertical force= Wt. x9.81

= 529.74 N

Frictional force=μN

= 423.792 N

Torque on Pinion= Tp =FL* Rpin

=6.197 N-M

Force required to Turn the wheel=TP/Radius of wheel

= 49.58N

For pinion radius

Select pressure angle

i.e. 20^0 or 14.5^0

For 20, no. of teeth =18

For 14.5, no of teeth =32

Hence, we select 20 pressure angle.

Dia of pinion = m*teeth

Then we check design for various forces and calculate the Diameter of pinion by,

We check design for PCD 38, 40,42,44,46,48,50,52 mm

- considering module m=2
- Pitch circle dia of pinion =52 mm
- No of teeth's=26
- b= 10*m=20 mm
- ha= 1*m=2 mm
- hf=1.25*m= 2.5 mm

1. Calculate beam Strength:-

Fb= σbp*b*m*yp

Yp= 0.484 -2.87/zp =0.3736

σbp = Sut/3 = 850 /3 = 283.33 n/mm^2

Fbp =283.33*20*2*0.3736

= 4234.2578N

2. Calculate Wear Strength:-

Fw = dp*b*q*k

Q= 2zr/(zp+zr)=2

K= 0.16*(300/100)^2 =1.44

Fw= 20*52*1.44*2=2995.2N

3. Effective Load

Feff = (Ka*Km*Ft)/Kv

Ka= 1.75

Km = 1

Ft = P/V

∴ The maximum torque is

Tmax = 37.5 Nm

Pmax = $(2\pi NT)/60$

Pmax = (2*π*18*37.5)/60 = 70.68 w

V= (π*dp *Np)/60 =49.03mm/sec =0.04903 m/sec

Ft= Pmax/v = 1442.1886 N

Kv= 3/(3+v)=0.9839

Feff=(1.75*1*1442.1886)/0.9839 = 2565.052N

4. FOS against Wear Failure

Fw= Feff*fos

FOS= 2995.2/2565.05= 1.167

∴ Also checking in Buckingham Eqn,

Fd = 21V(bc + Ftmax)/(21V+√(bc+Ftmax))

ep = 11+0.9(m+0.25√dp)

= 14.42μm

eg = 11+0.9 (m+0.25√dg) = 12.8μm

e = ep +eg

= $27.222*10^{-3}$ mm

C = 0.111*e[Ep*Eg/(Ep+Eg)]

= 312.7399 N/mm

[Ep = Eg=$207*10^{3}$]

Fd = 21V(bc + Ftmax)/(21V+√(bc+Ftmax))

= 95.364 N

Feff = Ftmax + Fd

= 2619.194 N

∴ Calculating factor of safety

Fw = Feff * FOS

FOS = Fw /Feff = 2995.2 /2619.194 = 1.44>1

∴ Hence Design is safe

4. Manufacturing

The manufacturing was carried out in workshop of DYPTC & also in Bhosari MICD. We manufacture Pinion of HMC, Rack on Rack cutting machine & Steering casing on VMC machine

4.1Rack & Pinion

We manufactured the rack & pinion with required specifications. The rack was manufactured by Rack cutting machine in Vishal Gears Bhosari MIDC. Also the pinion was manufactured on Horizontal Milling Machine in Vishal Gears Bhosari MIDC.

Figure.3. Manufacture Rack and Pinion

4.2 Steering Casing:

We manufactured the casing which guids rack and pinion through it on Vertical Milling machine(CNC) in Micromill Industries Bhosari. For that we select Al 6061 Alloy because of its low weight.

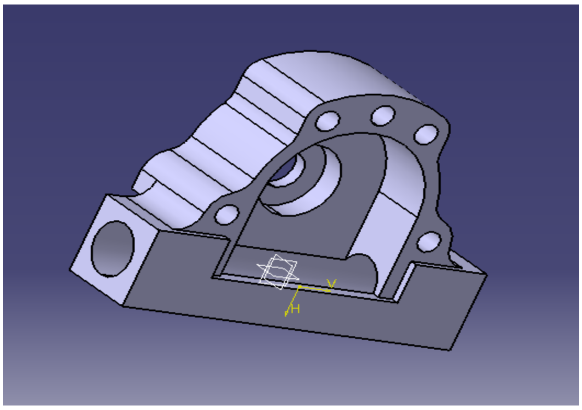


Figure.4. Steering Casing

Also the tie rods, steering column and clevis joint we manufactured in workshop of DYPTC Ambi

4. CONCLUSION

Its Conclude that to improve the steering geometry i.e. reverse Ackerman geometry, which helps the driver to avoid the negative effect of cornering forces acting on vehicle &. Increases the space in cockpit area and the comfort of driver. Steering geometry can be optimized by using mathematical model for Ackerman condition for different inner wheel angles and select geometry for which percentage Ackermann as well steering effort is optimum.

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