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Design Methodology and Manufacturing of Rack and Pinion for All Terrain Vehicle

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***Abstract*—The main purpose of this paper is to provide the methodology for design and manufacturing of manual rack and pinion steering system. According to the vehicle requirement for better maneuverability of the vehicle, the steering system of an atv is designed for the worst possible terrain and should provide maximum directional stability, pure rolling motion to the wheel with minimum turning radius. The objective of this paper is to design efficient, durable and relatively inexpensive steering system for atv by using manual manufacturing of rack and pinion mechanism.**

Keywords*— Manual manufacturing of rack and pinion,variable ackermann angles,geometry selection.

I. INTRODUCTION

The steering system is the most vital system in any automobile. It helps the driver in obtaining complete control on the maneuvering of the vehicle. The function of steering is to steer the front wheel with the driver's input in order to have complete control over the different types of terrains. In this project we have design our steering system and manufacture manual rack and pinion to meet our design requirements for Baja.

II. GEOMETRY SELECTION

Traction is an important factor in order to maneuver a vehicle Ackermann steering geometry provide pure rolling motion or prevent slipping of tires, which is appropriate for Baja where there is speed limit of 60 kmph. Whereas anti-Ackermann (reverse ackermann) geometry is used in high speed vehicles, which is appropriate for formula one cars.

Perfect Ackermann steering geometry states that the imaginary line from the steering pivot points inward so as to lie on a line drawn between the steering kingpins and the center of the rear axle. the inner wheel deflects more angle than outer wheel.as
shown in the fig1.

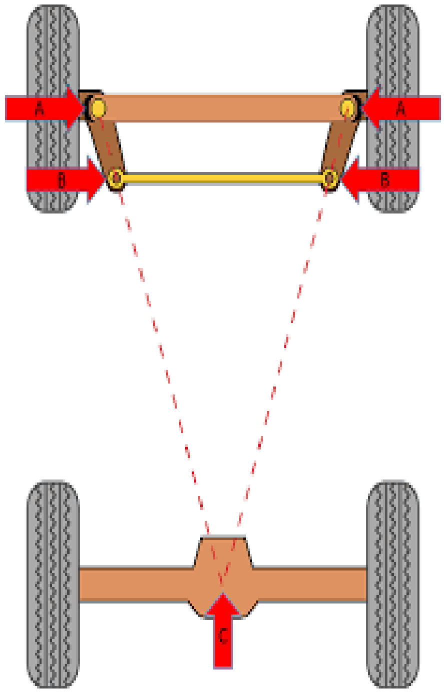

Fig1 shows Ackermann principle

A. GEOMETRY SETUP

1. Assume turning circle radius of outer front wheel
2. Calculate inner & outer angles from the assumed turning circle radius.
3. The inner and outer angles must not exceed more than 50°.
4. If it exceeds, then increase the assumed turning circle
   radius and again repeat the process.

B. CALCULATIONS

Table 1 predefined values of the vehicle

base length (b)	56”
Track width (a)	52”
Ackermann angle (α)	20°
Pivot to pivot distance(c)	43.7”

$$\text{Ackermann angle } (\alpha) = \tan^{-1}(c/2b) \qquad (1)$$

we obtain α =22.79°.

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Now assume the turning circle radius of outer front wheel and from that, calculate the outer angle.

$$R_{of} = b/\sin\phi + ((a-c)/2) \qquad (2)$$

Let assume $R_{(of)}$=3m and we get ϕ=29.43°
Now

$$\cot\phi - \cot\theta = c/b \qquad (3)$$

ϕ = outer angle
θ= inner angle
c = distance between pivot points
b= wheel base

Now from the above equation of correct steering angle, inner angle can be easily calculated.

$$\theta = 46°.$$

The obtained values of inner and outer angles are implemented in lotus software.

Arrange the geometry in such a way that the calculated values of inner and outer angle are obtained in the software. shown in table2.

III. SIMULATION IN SOFTWARE

Now implementing the calculated inner and outer angles in lotus software, try to arrange the inner and outer track ball joint points in such a way that we get the same values of inner and outer angles with the same turning circle radius.

While designing the tie rod, it must be arranged parallel to both a- arm, the length of the tie rod must be near to the average length of upper and lower a-arm respectively. This will help to reduce the bump steer and camber gains.

Remember in lotus software, the obtained turning circle radius is measured from cg point.

Table2 sfd file of lotus software

Steer travel (mm)	Toe angle (lhs)	Toe angle (rhs)	Camber angle (°)	Camber angle (°)	Ackermann (%)	Tcr (mm)
30	-29.25	49.76	-3	9.21	101.4	1872
20	-20.03	26.03	-2.35	4.51	74.6	3406
10	-10.39	11.70	-1.37	1.087	67.38	7315
0	0	0	0	0	0	0
-10	11.70	-10.39	1.087	-1.37	67.38	7315
-20	26.03	-20.03	4.51	-2.35	74.6	3406
-30	49.76	-29.25	9.21	-3	101.4	1872

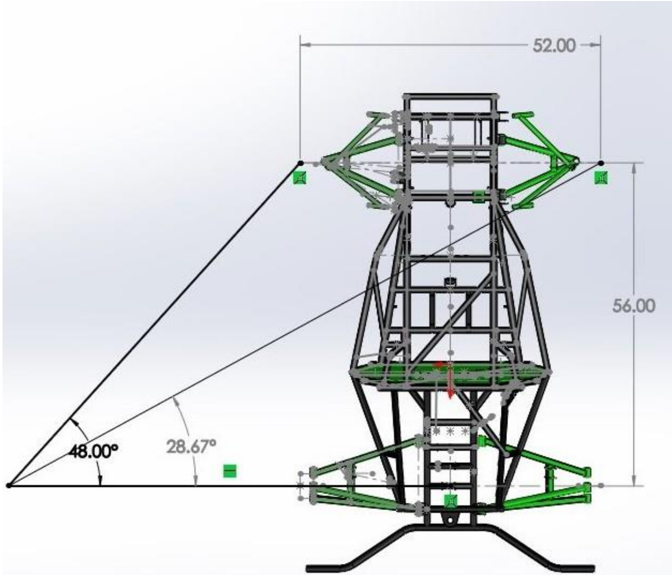

Fig 2 angles and dimensions.

Table3 represents Obtained values

Steering wheel turns (lock to lock)	0.5
Inner angle	28°
Outer angle	48°
Steering ratio	2.36:1
Steering wheel diameter	8”
Steering arm length	59mm
Rack length	465mm
Tie rod length	210mm

IV. RACK AND PINION CALCULATION

The value of rack travel is obtained from the software and assume the number of turns (lock to lock).

For the dimension of rack and pinion we have following formulas below

$$\text{Rack travel} = \pi * d_{pi} * \eta \qquad (4)$$

η=no of steering wheel turns
d_{pi} = diameter of pinion

$$60=3.14*d*0.5$$
$$d_{pi} = 39 \text{ mm}$$

Now from the standard values of module (as per the convenience). Let us assume m = 1.5. from this the number of teeth on pinion is easily calculated.

$$M=d/t_{pi} \qquad (5)$$

$$1.5=39/t_{pi}$$

$$T_{pi} = 26(\text{teeth on pinion})$$

T_{pi} = no of teeth on pinion

The module for rack and pinion will be same in order for messing of both the teeth.

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$$m = d_{pi}/t_{pi} = d_{ra}/t_{ra} \quad (6)$$

The pitch circle diameter for rack is infinite but we have the travel of pinion (i.e. Rack travel) from that value, convert the rack travel length into circular pitch diameter (only for the calculation purpose).

$$\text{Rack travel} = 3.14 * d(t)$$
$$d(t) = 19$$

The value of d(t) is determined, so from that, gear ratio of rack and pinion is obtained and from the gear ratio the total number of teeth on rack is obtained.

$$39/26 = 19/t_{ra}$$

$$t_{ra} = 12.66 \text{ round off} = 13 \text{(teeth on rack).}$$

Steering ratio

The steering ratio is defined as the ratio of steering wheel rotation angle to steer angle at the road wheels.

$$\text{Steering ratio} = 90+90/28+48 \quad (7)$$

$$2.368:1$$

Table 4 shows dimensions of rack and pinion

Quantity	Values
Rack length	461mm
Number of teeth on rack	13
Number of teeth on pinion	26
Diameter of pinion	39mm
Module of rack and pinion	1.5
Pressure angle	20°
addendum	1.5mm
dedendum	1.875mm

Table 5shows list of materials

Object	Material
Rack	En19
Pinion	En41b
Steering casing	Aluminium series 6
Steering knuckle	Aluminium series7
Steering wheel	Aluminium
Steering column	Din2391
Tie rod	Din2391

Fig3 shows manual manufacturing of pinion

Fig4 shows manual manufacturing of rack.

V. *Tuning setup*

In Baja, the track of maneuverability consist of sharp turns so by pure rolling motion it is not possible to take those sharp turns, so we came up with a variable Ackermann angle in which there is a plate attached to the upright (knuckle) and this plate consist of various tie rod attachment points due to which there is a change in Ackermann angle and steering arm length as show in fig6.

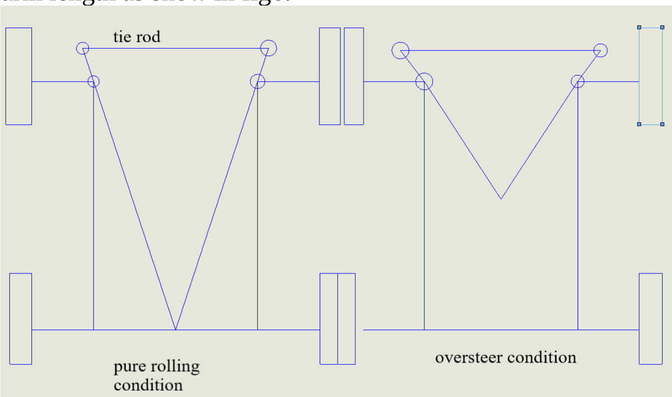

Fig5 shows the Ackermann conditions

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So, we can achieve both oversteer and pure rolling motion in same vehicle when needed. For example, pure rolling motion in suspension event and oversteer condition in maneuverability.

Fig 6 shows variable steering arm length plate

VI. CONCLUSION

The manual rack and pinion are only used in light weight vehicles. The values calculated in the paper may differ practically due to improper steering geometry or due to steering linkages errors, so these values are useful to understand the interdependency of the quantities on each other and to design an ideal manual rack and pinion system for the vehicle.

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