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Tripod Steering For Better Maneuverability of Quad-Bike

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Abstract – *All terrain vehicles, as the name suggest, are designed to fulfill needs in rough terrain regions such as Hills, farms, borders etc, where on road vehicles can't perform well. Steering mechanism must be designed considering the off-road conditions and should give better stability, maneuverability& minimum possible turning radius. Human comfort as well as steering effort is important parameter that should be considered while designing steering system. The objective of this paper is to use 'Tripod Steering Mechanism' (Bell Crank lever Steering Mechanism) for a quad bike .Rack & pinion is not suitable due to limiting steering ratio and use of handle bars over steering wheel. Bell crank lever is easy to design, manufacture and has comparatively less production cost.*

Key Words: **Quad-Bike, Steering ratio, Creo, Ansys, Tripod plate.**

1. INTRODUCTION

Steering system is one of most important part of an automobile that is used to give directional stability to the vehicle. The basic aim of steering is to ensure that the wheels are pointing in the desired directions. This is typically achieved by a series of linkages, rods, pivots and gears. [1]

Ackerman Steering Mechanism is generally used in all vehicles. The significance of Ackermann geometry is to avoid the need for tires to slip sideways when following the path around a curve. The geometrical solution to this is for all wheels to have their axles arranged as radii of circles with a common centre point. As the rear wheels are fixed, this centre point must be on a line extended from the rear axle. Intersecting the axes of the front wheels on this line as well requires that the inside front wheel is turned, when steering, through a greater angle than the outside wheel. [2]

Among rack and pinion mechanism, steering box mechanism and tripod steering mechanism, tripod steering is suitable for quad bike because of the limiting steering ratio. The design was finalized using CREO 3.0 and tripod plates were analyzed in ANSYS 14.5.

2. DESIGN OF STEERING SYSTEM

2.1. Ackerman Principle

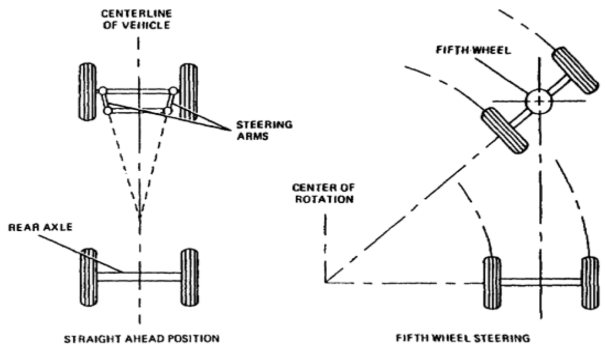

Fig -1: Schematic diagram of Ackerman Steering Mechanism

Ackerman principle states that all wheels should be rotated at one point. From the fig all the wheel have different turning radius, this conclude that all 4 wheel will have different angular velocity. If vehicle is taking left turn the front right wheel will have highest angular velocity than others as it has to cover larger distance & therefore its speed will be high. The left rear wheel will have lowest angular velocity so its speed will be low as compared to others.

2.2. Selection of parameters

- Wheelbase : 44 inches
- Front track width: 42 inches
- Steering ratio :1
- Steering effort : 20.66N
- Kingpin offset : 70 mm
- Kingpin inclination: 8°
- Castor angle : 6°
- Tire width : 5 inches

Wheelbase and track width are selected considering the suspension geometry, handling & stability. As in quad bike handle bars are used instead of steering wheels, the steering ratio required is 1. Steering effort can be calculated analytically. The kingpin offset and inclination was decided by considering the packaging of wheel assembly inside the rim and scrub radius. Tire width is one of the important factors affecting steering effort. It should have enough contact patch and minimum steering effort. Castor angle is selected such a way that it gives optimum self alignment torque for better handling.

2.3. Tripod Dimensions

Iterations were done on steering arm length and the dimensions of tripod plate. The best suitable result was then selected considering maximum Ackermann percentage.

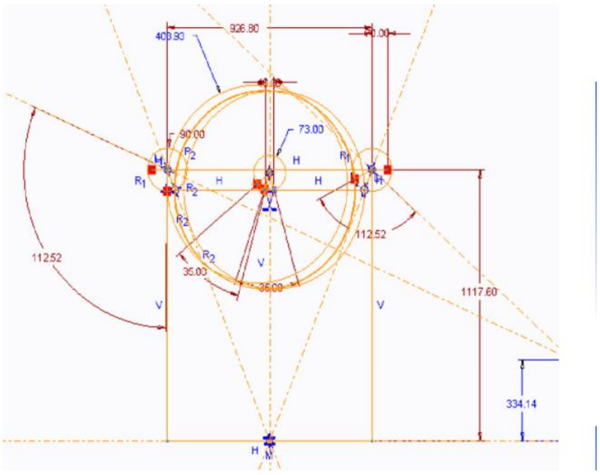

Fig-2: Iteration for finding percentage Ackerman

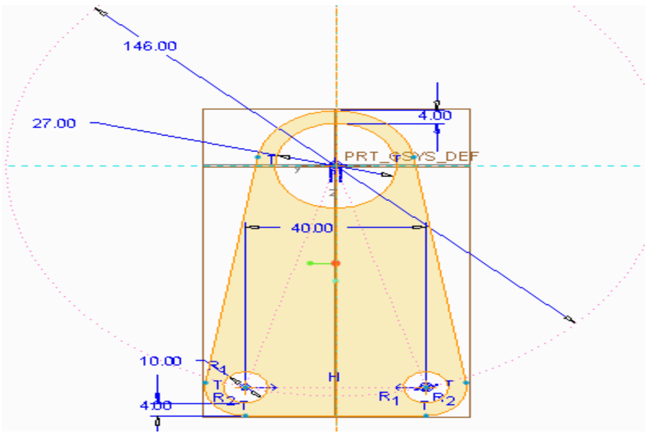

Fig -3: Tripod dimension

Steering geometry	Ackermann Geometry
Steering mechanism	Tripod mechanism
Ackermann angle	22.52°
Steering arm length	90
Tie rod length	424.63 mm
Inner wheel lock angle	40.89
Outer wheel lock angle	23.16
Percent Ackermann	70.14°

Table-1: Design Values from iteration

From above iteration,

Percentage Ackerman = (1170.60- 334.14)/1170.60 *100

= 70.14%

2.4. Calculations

Parameters	Values
Wheel Base	44”
Front Track Width (l)	42”
Track (b)	926.8 mm
Tyre width (w)	127 mm
Front axle load	90 kg
Load on each tire	45 kg
Scrub radius (e)	26.12 mm
Kingpin Offset	70 mm
Steering arm length	90 mm
Turning radius of C.G of vehicle(considered for calculation purpose)R	3 m
Turning radius of inner wheel Ri	3 - 0.5334 = 2.4656
Turning radius of outer wheel Ro	3 + 0.5334 = 3.5334
Coefficient of friction for dry road	0.7
Length of steering handle	700 mm
Turning velocity of vehicle	4.53 m/s
Height of C.G. of vehicle	17.35”
Mechanical trail	46.54 mm

Table-2: Input parameters

2.4.1. Static Calculations:

Ackermann angle = $\tan^{-1}(b/2l)$

= tan-1 (926.8/2*44*25.4)

= 22.52

Radius of gyration (k) = $w^2/8$

= $127^2/8$

= 2016.125 mm

Effective torque arm length (h) = sq. root ($k+e^2$)

= ($2016.125+26.12^2$)

= 51.94mm

Moment at kingpin = g*W*h*μ

= 9.81*45*51.94*0.7

= 16050.239 N-mm

Force at tie rod ends = moment at kingpin/ steering arm Length

= 16050.239 /90

=178.335 N

Force at Tripod = 178.335 /0.9

=198.151 N

Moment at tripod = Force at tri pod*Arm of tri pod

=198.151*73

=14465.03 N-mm

Moment at tripod = moment at steering handle

14465.03= Steering effort / handle length

Steering effort =14465.03/700

Steering effort = 20.664 N

2.4.2. Dynamic Calculations:

Consider vehicle taking left turn,

Cornering 'g' force = v^2/Rg

= $4.53^2/3*9.81$

=0.697 N

Weight transferred on right tire during cornering = (g- force*height of C.G.* front axle load)/track width

= 0.697*13.27*90/42

= 19.819 kg

Weight on right tire (Wr) = W + weight transferred during cornering

=45+19.819

=64.81 kg

Weight on left tire (Wl) = W - weight transferred during cornering

=45-19.819

=25.181 kg

Lateral force on left tire = $Wl*v^2/Ri$

=25.181 $*4.53^2/2.4656$

=209.578 N

Lateral force on right tire = $Wr*v^2/Ro$

=64.81 $*4.53^2/3.5334$

=376.39 N

Total lateral force = lateral force on left tire + lateral force on right tire

= 209.578 +376.39

= 585.97 N

Moment at kingpin = total lateral force*mechanical trail

= 585.97 *46.54

= 27271.255 N-mm

Self aligning torque = lateral force*contact patch/6

= 585.97 *127/6

=12403.03 N-mm

Total torque = moment at kingpin + self-aligning torque

=27271.255+12403.03

= 39674.286 N-mm

Force at tie rod = total torque/steering arm length

= 39674.286/90

=440.825 N

Force at inner tie rod end = 2*force on tie rod

= 2*440.825

= 881.65 N

Moment at steering shaft = force at inner tie rod end * tripod length

= 881.65*73

=64360.509 N-mm

Theoretical steering effort = Moment at steering shaft / (Steering handle length)

=64360.509/700

=91.943 N-mm

3.0 ANALYSIS USING ANSYS

The steering system is designed in CREO 3.0 and analysis is done in ANSYS for maximum deformation & maximums stresses.

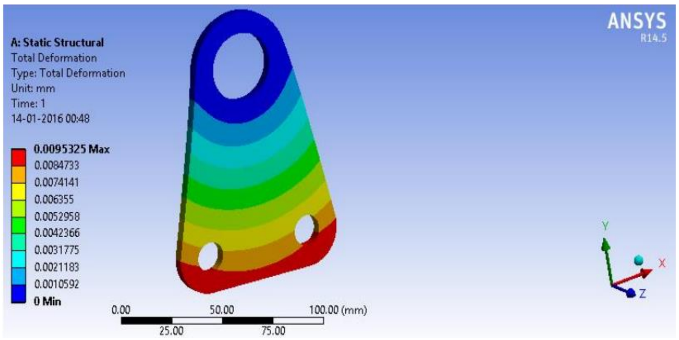

Fig-4: Maximum Deformation

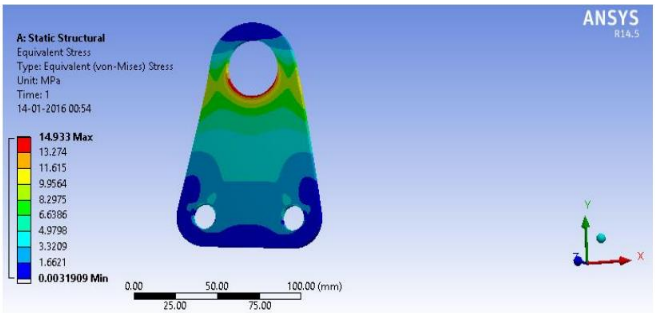

Fig-5: Maximum Stress (Von-Mises theory)

Sr. No	Parameter	Values obtained
1	Maximum deformation	0.0095mm
2	Maximum stress	14.93Mpa

Table-3: Results of analysis

4. IMPLEMENTATION OF TRIPOD MECHANISM

The designed steering system is manufactured and assembled in quad bike as shown in figure below & Quad-Bike is tested in various off-road conditions.

Fig-6: Assembly of Tripod steering

Fig-7: Quad bike

5. CONCLUSION

Tripod steering was installed on a quad bike and was tested on the various rough terrains. The results were better stability and minimum steering effort. Although it has limitation of having comparatively less Ackermann percentage, its best suited for the quad bikes due to steering ratio. The Ackermann percentage obtained was 70.14% and steering effort was 20.664N in static loading.

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