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Tripod Steering For Better Movability of Quad-Bike

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Abstract - *All-Terrain Vehicles, as the name suggests, are designed in a way to get best efficiency in the rough terrain regions such as Hills, Farms, Borders etc. whereas on road vehicles don't give adequate performance or results. Steering system that we use in the Quad Bike must be designed considering the off-road conditions and should give better maneuverability, firmness and minimum possible turning radius. Other parameters like Human Comfort should also be considered thoroughly while designing the steering system. The objective of this paper is to use a 'Tripod Steering Mechanism' for a Quad Bike. Rack and Pinion is not suitable due to limited steering ratio and use of handle bars over steering wheel. Tripod Mechanism is preferred because of the various parameters such as, it is easy to design, manufacture and has quite less production cost.*

***Key Words*: Steering ratio, Quad Bike, Solid Works, Ansys, Tripod plate.**

1. INTRODUCTION

The steering system can be considered as one of the most important part of an automobile that gives it a directional stability. The most conventional steering arrangement is to turn the front wheels using a hand operated handle bar which is positioned in front of the driver, via the steering column, which may contain universal joints to allow it to deviate somewhat from a straight line.

Other arrangements are sometimes found on different types of vehicles, for example, a tiller or re-wheel steering. The direction of motion of a motor vehicle is controlled by a steering system. Ackermann Steering mechanism is most commonly used in all the vehicles. The significance of Ackermann geometry is to avoid the necessity for tires to slip sideways while following a circular path. The available geometrical solution of this is to have the axles of the wheels arranged as radii of circles with a common centre point. As only the front wheels can move so this centre point must be on a line extended from the rear axle. A basic steering system has 3 main parts: A shaft that connects the handle bar to the tripod plate, a tripod plate that connects to the tie rods and these tie rods are connected to the wheels.

We've chosen Tripod Steering among all the available options such as Rack and Pinion, Steering Box Mechanism etc. because it has a limited steering ratio that helps in stability of a Quad Bike.

2. DESIGN PROCEDURE

2.1 Ackermann Principle

Ackermann steering geometry is used to change the dynamic toe setting, by increasing front wheel toe out as the car is turned into the corner. This typical steering system has tie-rod linkages and steering arms that form an approximate parallelogram, which skews to one side as the wheels turn. If the steering arms are parallel, then both wheels are steered to the same angle. Ackermann type of steering geometry ensures consistent and smoother ride and prevents the slipping of tires during cornering. Having a high Ackermann factor is useful in taking tight corners at a relatively lower speed.

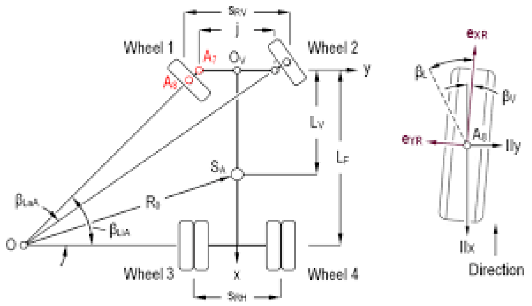

Fig -1: Illustrative diagram of Ackermann steering mechanism

2.2 Selection of Parameters

- Castor Angle – 5°
- Tire Width – 5 inches
- Steering Ratio - 1
- Steering Effort – 26 N
- Kingpin Inclination – 7°
- Wheel base – 43 inches
- Track Width – 40 inches

Caster angle is chosen by keeping the fact in mind that it gives optimum torque for better handling. In quad bike, handle bars are used instead of steering wheel, the steering ratio required is 1. Wheelbase and Track Width are selected on the basis of suspension geometry, stability and firmness whereas Kingpin offset and inclination is decided on the basis of packaging of wheel assembly inside the rim and scrub radius. Tire width is also one of the important factors in steering design. It should have a minimum steering ratio and contact patch.

2.3 Tripod Dimensions

Reiteration is performed on the Tripod plate's dimensions and steering arm length. After several considerations such as maximum Ackermann percentage, the best suitable results were taken thereafter.

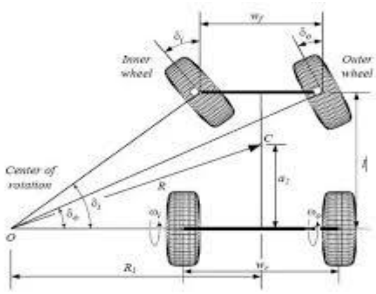

Fig -2: Reiteration for finding Ackermann Percentage

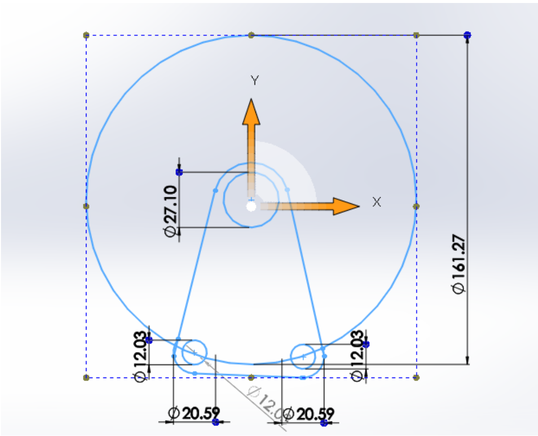

Fig -3: Tripod Plate Dimensions (1)

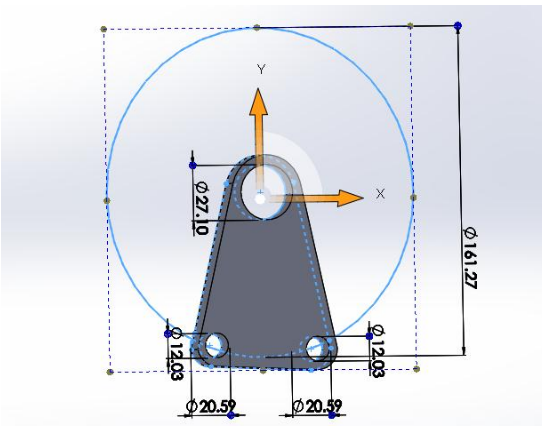

Fig -4: Tripod Plate Dimensions (2)

Steering Geometry	Ackermann Geometry
Steering Mechanism	Tripod Mechanism
Ackermann Angle	27.53°
Steering Arm length	3.93 inches
Tie Rod length	12.093 inches
Inner Wheel lock angle	25.9°
Outer Wheel lock angle	19.9°
Percentage Ackermann	94.07 %

Table -1: Design values from Reiteration

2.4 Calculations

Wheelbase	43 inches (1192.2 mm)
Track Width	40 inches (1016 mm)
Axle Length	29 inches (736.6 mm)
Caster Angle	5°
Kingpin Inclination	7°
Contact Patch	5.1 inches
Turning Velocity	5 m/s
Steering Arm length	3.93 inches (99.82 mm)
Radius of Wheel	11 inches (279.4 mm)
Load on each wheel	50 kg
Inner Turning Angle	25.9°
Outer Turning Angle	19.9°
Turning Radius (Right Wheel)	2.29 m
Turning Radius (Left Wheel)	3.25 m
Tripod Radius	4.868 inches
Height of CG	18 inches (457.2 mm)
Ackermann Angle	27.53°
Tripod Length	3.34 inches (84.83 mm)
Length of Steering Handle	800 mm
Tie Rod length	12.093 inches (307.16 mm)
Ackermann Percentage	94.07 %

Table -2: Input Parameters

2.4.1 Ackermann percentage

Ackermann Percentage is calculated from referring to the Designing Geometry Figure of the Steering system.
Inner Turning Angle (ϕ) = 25.9°

Outer Turning Angle (θ) = 19.9°

Ackermann Value,

$$= \tan^{-1}\left[\frac{Wheel\ Base}{\frac{Wheel\ Base}{\tan\theta} - Track\ Width}\right]$$

$$= \tan^{-1}\left[\frac{1192.2}{\frac{1192.2}{0.361} - 1016}\right]$$

= 27.53°

Ackermann Percentage:-

$$= \frac{\phi(Actual) \times 100}{Ackermann\ Value}$$

$$= \frac{25.9^{\circ} \times 100}{27.53^{\circ}}$$

= 94.07 %

2.4.2 Dynamic condition

- Turning Radius of Centre of Gravity = 2.6067766 m
- Turning Radius (Right Wheel) = 2.2961092 m
- Turning Radius (Left Wheel) = 3.2549338 m
- Height of Centre of Gravity = 457.2 mm = 18 inches

2.4.3 Static and Dynamic Calculations

I. Cornering Force

= (Turning Velocity) ^2 / (Turning Radius of Centre of Gravity x g)
= 5^2 / (2.6067766 x 9.81)
= 0.977613493 N

II. Weight Transfer at Cornering

= (Cornering Force x Height of C.G. x Axle Load) / Track Width
= (0.977613493 x 18 x 100) / 40
= 43.992 Kg

III. Weight on Right Wheel

= (Load on Right Wheel + Weight Transfer at Cornering)
= (50 + 43.992)
= 93.992 kg

IV. Weight on Left Wheel

= (Load on Left Wheel - Weight Transfer at Cornering)
= (50 - 43.992)
= 6.007 Kg

V. Lateral Force on Right Wheel

= (Weight on Right Wheel x Turning Velocity^2) /Turning Radius Right Wheel
= (93.992 x 5 x 5) / 2.2961092
= 1023.38 N

VI. Lateral Force on Left Wheel

= (Weight on Left Wheel x Turning Velocity^2) /Turning Radius Left Wheel
= (6.007 x 5 x 5) / 3.2549338
= 46.138 N

VII. Total Lateral Force

= Lateral Force on Left Wheel + Lateral Force on Right Wheel
= 46.138 N + 1023.38 N
= 1069.51 N

VIII. Moment at Kingpin

= Total Lateral Force x Mechanical Trail
= 1069.51 N x 24.444
= 26143.10 N-mm

IX. Self-Aligning Torque

= Lateral Force x Contact Patch/6
= 1069.51 N x130/6
= 23172.71 N-mm

X. Total Torque

= Moment at Kingpin + Self-Aligning Torque
= 26143.10 N-mm + 23172.71 N-mm
= 49315.81 N-mm

XI. Force at Tie Rod

= Total Torque/Steering arm length
= 49315.81 N-mm / 100
= 493.158 N-mm

XII. Force at Inner Tie Rod end

= 2 x Force on Tie rod
= 2 x 493.158 N-mm
= 986.316 N-mm

XIII. Moment at Steering Column

= Force at Inner Tie Rod x Tripod Length
= 986.316 N-mm X 85 = 83836.888 N-mm

XIV. Steering Effort

= Moment at Steering Column / Length of Steering Handle
= 83836.888 N-mm / 800 = 104.79 N-mm

3. ANALYSIS USING ANSYS

The above said steering is designed in Solid works and analysis is done in Ansys for most critical condition such as maximum deformation, maximum stress etc. Its main purpose is to generate the finite element model which consists mainly of nodes, elements and material property definition. It usually begins with the definition of the model geometry. Usually a CAD type mathematical representation defines the geometry of the structure.

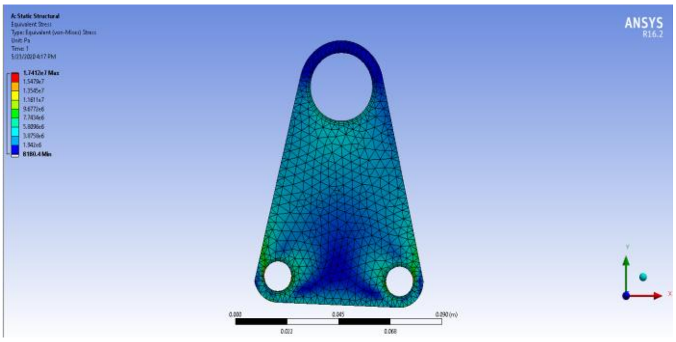

Fig -5: Maximum Stress (Von-Mises Theory)

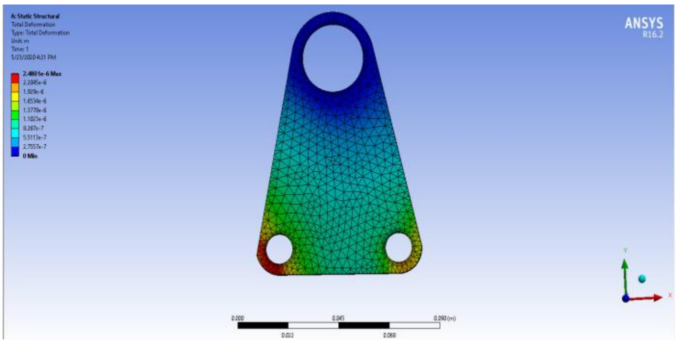

Fig -6: Maximum Deformation

S. No.	Parameter	Value Obtained
1.	Maximum Stress	1909.457 Pa
2.	Maximum Deformation	0.006147 m

Table -3: Results of Analysis

4. IMPLEMENTATION OF TRIPOD MECHANISM

When the driver turns the handle bar, a shaft from the steering column turns a tripod plate. The tripod plate moves tie rods that connect to the front wheels. The tie rod moves the front wheel to turn the vehicle right or left. This mechanism is useful for the movement of the vehicle in the desired directions. After all the designing and analysis, the tripod steering system is manufactured and assembled in Quad Bike. The assembly is shown in the fig. 7.

Fig -7: Assembly of Tripod

Fig -8: Quad-Bike

5. CONCLUSION

Steering system is one of the most important features in automobile. All the directions and movement of the wheels of the vehicle will be controlled by this system. These components must always be in good condition so that steering system will run smoothly and more efficiently to provide the driver with good experience of driving on the road. The results were of better stability and minimum steering efforts. Having a high Ackermann factor is useful in taking tight corners at a relatively lower speed. The Ackerman percentage was obtained 107% and Steering effort was 20.664 N.

6. REFERENCES

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