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DESIGN OF STEERING AND BRAKING SYSTEM OF ELECTRIC SOLAR VEHICLE

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Abstract **-** The project aimed at designing, and testing of steering and braking system for a student of Electric Solar Vehicle and their integration in the whole vehicle. The car has been designed to the best of its possible. The primary objective of this project was to identify and determine the design the parameters of a vehicle with a proper study of vehicle dynamics. This project helped us to study and analyzed the procedure of vehicle steering and braking system designing and to identify the performance affecting parameters. It also helped us to understand and overcome the theoretical difficulties of vehicle design.

Keyword : Disc Braking System , Steering system.

I. INTRODUCTION :

Steering system converts the rotation of the steering wheel into swiveling movement of the road wheel in such a way that steering wheel rim turn a long way to move a road wheel a short way. Brakes has been an essential part of today's modern automotive system. Brakes are mechanical device that stops or retards the motion of moving member by absorbing kinetic energy and converting it into heat energy. In case of an automobile this moving member is wheel. Brakes are not only important for stopping the vehicle but also for controlling it. Many different types of brakes are available in the market. Mostly disc brakes are preferred in solar vehicle. Because, weight reduction is one of the prime concerns for a race car; especially solar vehicles.The steering system converts the rotation of the steering wheel into a swiveling movement of the road wheels in such a way that the steering-wheel rim turns a long way to move the road wheels a short way.The steering effort passes to the wheels through a system of pivoted joints. These are designed to allow the wheels to move up and down with the suspension without changing the steering angle. They also ensure that when cornering, the inner front wheel - which has to travel round a tighter curve than the outer one - becomes more sharply angled The joints must be adjusted very precisely, and even a little looseness in them makes the steering dangerously sloppy and inaccurate. There are two steering systems in common use - the rack and pinion and the steering box. On large cars, either system may be power assisted to reduce further the effort needed to move it, especially when the car is moving slowly.A disc brake is a type of brake that uses calipers to squeeze pairs of pads against a disc or rotor to create friction. This action retards the rotation of a shaft, such as a vehicle axle, either to reduce its rotational speed or to hold it stationary. The energy of motion is converted into waste heat which must be dispersed.

II. DESIGN AND CALCULATIONS :

For Steering System :
Specifications:-
Steering wheel– diameter = 0.2286m, with 3 rims
Rack- mild steel, 0.39584m length
Wheelbase = 1.450 m;
Lock to Lock turns = 3
Turning radius =2.059m
Camber = 1.5°

Castor = 4°

Table 2.1:Selection of Steering Mechanism

Steering System	Rack and Pinion	Worm and Roller	Recirculating ball screw	Cam And Lever
Cost	4	4	3	3
Availability	4	3	2	4
Weight	4	3	2	3
Efficiency	3	3	4	3
Total	15	13	11	13

We are using a Side rack and pinion steering system. The steering system that we are using has a linear travel of 131.9469 mm. It has a ratio of 540 degree center to lock turn of the steering wheel, which is considerable for the race track. A small ratio will allow quick turns with a smaller input from the driver, while being more precise at the same time. We have managed a turning radius of lock to lock travel of 3 revolution of a turn wheel. The front suspension was designed to maintain excellent steering geometry at all suspension positions. This improves the handling of the vehicle since the suspension is seldom at the normal ride height position.

Fig. 2.1 Rack and pinion steering

2.2 Calculations:

It was measured that for a full travel of the rack of 152.48 mm the pinion has to be rotated 2 turn (720°). Therefore for one turn, the rack travel will be: X_0 =152.48/2

So, X_0 = 76.24mm

Considering the pinion to make one revolution then the input steering movement is: $Xi = 2\pi R = 718.16mm$

Where, R = 114.3mm is the radius of the steering wheel

Hence the output rack movement is: $X_0 = 2\pi r = 76.24mm$.

So, $r = 76.24/2\pi$
= 12.14mm.

Then, the steering movement ratio (MR) can be calculated as input movement over output:

$MR = Xi/X_0$

$= 2\pi R/2\pi r$

=718.16/76.24

= 9.4197

Therefore the movement ratio is 9.4197:1**,**we needed to know the movement ratio in order to determine the output load transmitted to the tie rods for a given input load.

For an effort of 20 N applied by each hand on the steering wheel and considering no friction, the output load will be:

$Fo = Fi * MR = 2 * 20 * 9.4197 = 376.78$ N

therefore the load transmitted to the tie rods is **376.78 N**.

2.3 Ackermann condition:

For the Ackermann analysis, the Ackermann condition is used to determine the relationship between inner and outer wheel in a turn and the radius of turn.

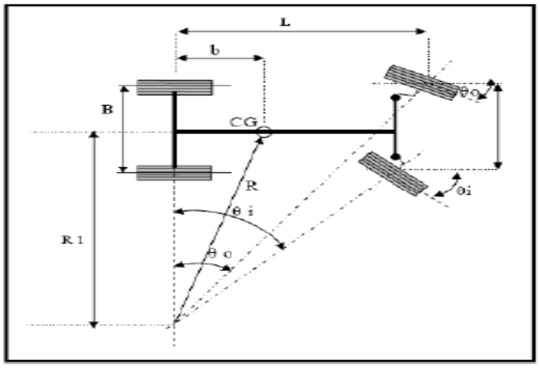

Fig. 4.2Ackerman Geometry for front wheel steering system

2.4 General equation:

$\cot\theta o - \cot \theta i = B/L$

Where,

θo = turn angle of the wheel on the outside of the turn

θi = turn angle of the wheel on the inside of the turn

B=track width

L = wheel base

b = distance from rear axle to center of gravity of vehicle.
From the general equation we can calculate the turn angle of the wheel on the outside of the turn for a given inside wheel angle as follows:

L = 1450mm

B = 980mm

A=1008mm

$\theta i = 45°$

$\cot(\theta o) - \cot(45) = 980/1450$

So, $\theta o = 30.82°$

The minimum radius of turn R can be determined from the geometry:

$R = \sqrt{(a^2 + L^2 \cot^2\alpha)}$

$\cot\alpha = (\cot\theta o + \cot\theta i)/2$

$\cot\alpha = (\cot 45° + \cot 30.82°)/2$

$\alpha = 36.77°$

$R = \sqrt{(0.69^2 + 1.45^2 \times \cot^2 36.77)}$

R = 2.05 m

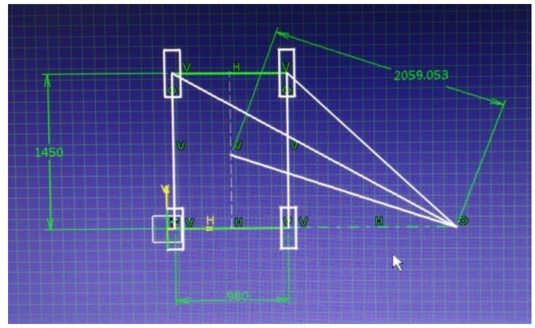

Figure.2.4Geometrical dimension steering system

Therefore the minimum radius of turn of the vehicle around its Centre of gravity for a maximum inside wheel turn of 45 degrees is about 2.05 meters.

By geometry of steering system it is show that the value calculated from theoretical is nearly same as that of geometrical value so this steering calculation are right

2.5 Steering effort:

Radius of steering = 114.3 mm
Radius of pinion = 13.462 mm
Wt. on one wheel = 62.5 kg
= 62.5×9.81 N
= 613.125 N
Max. coeff. of friction = 1
Torque on pinion = 613.125×13.462
= 8253.88 N-m
Steering effort = 8253.88/rad. of steering
= 8253.88/114.3
Steering effort = 72.21 N

2.6 Selection of steering mechanism:
Rack and Pinion steering system:

From all manual steering systems the more suitable is Rack and Pinion steering for the following reasons. -Has a simple construction,
-Is cheap and readily available
-Has a high mechanical efficiency
Gear box calculation of rack and pinion steering system is rarely closed to the Nano steering system hence we are select the standard rack and pinion steering box selected is from a Nano and has a 6 teeth on pinion and gear has 16 teeths and pitch on the rack of 4.5mm.

Sr. No.	Parameters	Dimensions(mm)
1	Tie rod length	150
2	Rack length	395

Table No.2.6 Dimensions of rack and pinion steering system

For braking system:

2.7 Design Of Braking System:

2.7.1 Stopping Distance Calculation:

D = V2/ [2×g× (μ+s) ×3.62]
V=Speed in Km/hr = 45km/hr
g=acceleration due to gravity 9.8 m/s2
μ=mean coefficient of friction =0.6
S=Roadway grade (it is 0.05 for flat-road)
D = 452/ (2×9.81× (0.6+0.05) ×3.62) =12.25 m

2.7..2 Deceleration:

Deceleration = V2/stopping distance
=12.52/ (2×12.25)
= 6.377m/sec2.

2.7.3 Weight transfer calculation:

Dynamic weight distribution is given by,
WF = $(x+\mu h)(x+y)$ = 1640.35N
WR = $(y-\mu h)(x+y)$ = 812.15N
Therefore, weight transfer is about 66.88 : 33.11 front: rear.

2.7.4. Calculation for Front:-

Diameter of calliper cylinder = 28 mm
Area of calliper cylinder = 2 × 615.75 mm2
= 1231.5 mm2

Weight on one of the front wheels, WF1 = WF/2
=1640.35/2
= 820.175N
Frictional force on wheel, FW1=WF1× μ
= 820.175×0.6
= 492.105 N
Braking torque on tyre, T = FW1× R
= 492.105× 250
= 123026.25 N-mm

To overcome this braking torque same torque is to be produced by the force on disc.
Therefore,
T = Ft× r
Ft = 123026.25/ 85 = 1447.36 N
Force applied by brake pads
F = Ft / μ
= 1447.36 / 0.4 = 3618.41 N
Pressure produced by the master cylinder = F / area of caliper piston

= 3618.41 / 1231.50
= 2.93 N/mm2 = 29.3 bar

Force on master cylinder F2
= pressure ×area of master cylinder
= 2.93 × 285.02 = 837.44N

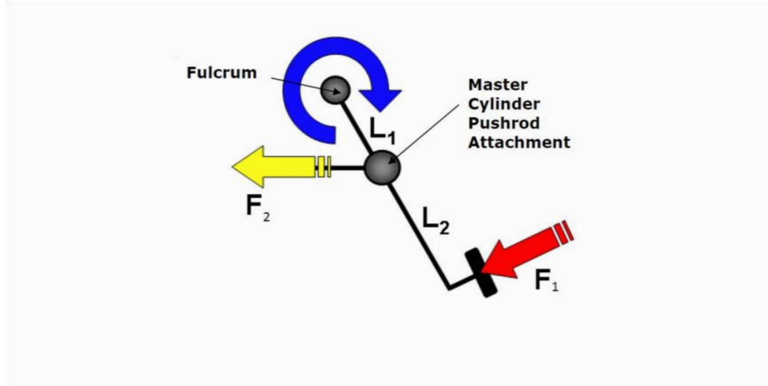

Figure 2.7.4 Pedal Ratio 5:1

Therefore, force on brake pedal, F1 = F2 / 5
= 837.44 / 5
=167.488 N.
That is 17.07 Kg.

2.7.5Calculation for Rear:

Diameter of caliper cylinder = 30 mm
Area of caliper cylinder = 1 × 706.85 mm2
= 706.85 mm2.

Weight on one of the Rear wheels WR1 = WR/2
= 812.15 / 2
= 406.075 N.
Frictional force on wheel FW1 = 406.075× 0.6
= 243.645 N
Braking torque on tyre T = Fw1× R
= 243.645× 250
= 60911.25 N-mm
To overcome this braking torque same torque is to be produced by the force on disc.
Therefore,
T = Ft× r
Ft = 60911.25 / 85
= 716.60 N
Force applied by brake pads F = Ft / μ
= 716.60 / 0.4
= 1719.50 N
Pressure produced by the master cylinder = F / area of caliper piston
= 1719.50 / 706.85
= 2.43 N/mm2.

= 24.3bar.

Force on master cylinder F2 = pressure ×area of master cylinder
= 2.43× 285.02 = 693.34 N

Therefore, force on brake pedal F1 = F2 / 5
= 693.34 / 5
= 138.66 N
That is 14.13 Kg.
Therefore, Average required force on brake pedal is F = (167.488+138.66)/2
= 153.074N.
Hence, in this way we have calculated correct value of brake pedal force. The standard value of brake pedal force for disc brake is equal to 250N (or less than 250N).

2.7.6 Braking Time of a Vehicle:

The total braking force reacted between the vehicle and the ground
F (total) = (2 × frictional force on front wheel + frictional force on rear wheel)
= (2 × 492.105 + 243.645)
= 1227.855 N.
T(stop) = (v × mv) / (F)total
= (12.5 × 250) / 1227.855
= 2.54 Sec

2.7.6 Specification Table :

Disc Dimensions	Front	Rear
Diameter (mm)		
Braking Torque on Tyre (N-m)		
Brake Pedal Force (N)		
Diameter of Master Cylinder(mm)		
Master Cylinder Stroke (inch)		
Leverage		
Stopping Distance(m)		
Deceleration(m/s2)		
Dynamic Weight Distribution		
Pressure Produced in Master Cylinder(Bar)		
Braking Time of Vehicle (Second)		

Specification Parameter	Name of Parts Company
Front Disc	Honda Aviator110
Rear Disc	Honda Aviator110
Front Caliper	Honda Aviator110
Rear Caliper	Honda Aviator110
Master cylinder	Maruti 800
Braking Effort	153.074N
Wheel Lock First	Simultaneous
Brake Fluid	DOT3
Tyre Diameter (mm)	500

III. CONCLUSION :

Steering system is one of the most important feature in automobile. This system controls all of the direction and movement of our vehicle. Besides the component that are Involved in the system are steering shaft, steering gear box, Pitman arm, steering knuckle arm, etc. This component must always in good condition so that steering system will run smoothly and more efficient to provide the driver with good experience of driving on the road. In this project we are utilizing disk brake for braking system that is Honda Aviator 110'Disc Brake. Because, disk brake are light in weight and fast response and successfully done the brake design calculation including stopping distance, brake pedal force, braking time of a vehicle.

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