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DEVELOPMENT OF PEDAL POWERED HYBRID TRICYCLE

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Abstract- *Me and my co-authors aim towards designing, validating and fabricating a three wheeled hybrid human powered electric vehicle driven by single driver, which has a capability to act as a good viable option for city local transportation. The vehicle would be capable of being driven electrically as well as by a single driver. We also provided this tricycle with self-charging concept. During pedaling the batteries are being charged and after charging driver can switch to the auto-powered mode. Also this Batteries can be charged by means of external power supply. Thus This vehicle is capable of being driven by three energy sources. We designed the vehicle keeping ergonomics and value engineering in mind. Our Vehicle further is designed keeping in view the comfort and minimum fatigue to the driver, Minimum stopping distance, better stability at High speed.*

Keywords- *Delta and Tadpole, DOF, Electric Motor, FEA, FOS, Gears.*

I. INTRODUCTION

Most of the cities and towns in India are highly polluted. In India there are presently close to 19 million petrol powered two wheelers and about 1.7 million petrol and diesel-powered three-wheelers and their population is growing at rate of about 15% per annum. Recent incident of banning of six seated diesel tempos in Pune attests to this pollution problem. There is therefore an urgent need to introduce in cities and towns of India an environmentally sound transport system which is cost effective and which provides large scale employment for urban and rural poor. An electric cycle rickshaw can provide a non-polluting, point-to-point and a very silent transport system for urban and rural areas of India. Besides it is a very energy efficient and cost effective vehicle. Work done at our Institute has shown that improved cycle rickshaw powered by an electric motor and batteries has a potential to provide an attractive alternative to petrol and diesel-powered. We provide high, medium and low gears for plane road, rough road and slopes. We also provided this tricycle with self-charging concept.

Our Design of Tricycle is
- Extremely reliable
- Highly maneuverable
- Comfortable easy ride
- Very economical to run
- Simple to maintain

II. EXISTING CYCLE RICKSHAW SCENE

The gearing and the mechanical advantage of the pedal is very poor in existing cycle rickshaw. Hence the rickshaw puller has to work very hard while climbing even a slight slope. A common sight is of the rickshaw puller getting down and pulling on foot the rickshaw with passengers. The braking system is also very poor with only front brakes on the rickshaw. Thus when going downhill at high speeds sudden braking produces a catapult affects which results in over-turning of the rickshaw. Aerodynamic drag which is the resistance offered to the vehicle by wind and other factors of the system is very high. Thus it requires a highly Developed design that should be adopted which can together reduce them health problems of pullers, comfort ability of passengers and carriage of heavy goods with less effort so as to avoid the fatigue to the rickshaw puller. Further in the heavy traffic areas it often become difficult for the rickshaw pullers to take a U-turn and hence this problem has also been considered while designing the vehicle which helps in a smooth and very less turning radius.

III. TECHNICAL SPECIFICATIONS OF THE HYBRID VEHICLE

Table 1. General Specification

Vehicle Design	Recumbent Delta
Frame Material	Mild steel
Vehicle Dimensions	Track width- 40" Vehicle length- 82" Vehicle width- 43"
Expected Vehicle Weight	80kg
Total Load Carrying Capacity	2200 Newton /225Kgs
Wheel Configuration	2 Rear 1 Front
Wheel Size	Rear 26.5" × 2" × 20" Front 22" × 1.5" × 20"

Table 2. Steering

Steering Type	Direct linkage type
Turning Radius	3.0 meters

Table 3. Brakes

Braking	Shoe Brakes at Front and Band Brake at rear wheels
Ground Clearance	6"

Table 4. Electrical System

Motor	48V, 0.5hp (350W), PMDC
Battery	SLA (12V, 9Ah, 4 in Numbers)

IV. VEHICLE PERFORMANCE

A. Maximum amount of torque that can be applied to the rear axle before the wheels will slip.

$W_{total} = W_{person} + W_{vehicle}$
$= (M_{person} + M_{vehicle}) \times g$
$= (80+80) \times 9.8$
$= 1570$ N

It is assumed that 80% of the total vehicle weight is distributed throughout the rear of the vehicle.

$W_{rear} = 0.8 \times W_{total} = 1255.7$N

The weight on each rear tire is now calculated,

$W_{tire} = W_{rear} / 2 = 628$ N

The normal force on each rear tire is equivalent to the weight on each rear tire = $N_f = 628$ N

The static coefficient of friction for rubber on concrete has been observed to be 0.7 (published in Jones and childers report)

The frictional force on each rear tire,

$$\mathbf{F_{sf} = 0.7 \times N_f = 439.5\ N}$$

Radius of rear tyres, **r = 13.25 in = 0.337 m**

The amount of torque on each rear tire is calculate $\mathbf{t_{max} = F_{sf} \times r}$

$\mathbf{t_{max} = 148.11\ N \cdot m}$

The amount of torque at the center of the rear axle is twice as much as the torque on each rear wheel

$\mathbf{T_{max} = 2 \times t_{max}}$

T_{max} = 296.22 N·m
T_{max} is the maximum amount of torque that can be applied before slipping.

B. Minimum amount of torque to get the vehicle moving

There are three types of vehicle resistance**,** Aerodynamic resistance, Rolling resistance, and Gravitational resistance. The coefficient of rolling resistance is estimated to be about 0.0055 for cycle tire.
On road = μ_r = 0.0055
Rolling friction, **$F_r = \mu_r \times W_{total}$ = 8.635 N**
Assume that the internal mechanical friction is 30% of the rolling friction,
$F_{internal} = 0.3 \times F_r$ = 2.59 N
$F_{total} = F_r + F_{internal}$ = 11.23 N
This means that if a minimum force of 11.23 N is applied, the vehicle will move.
Torque required on one rear wheel, t = f × r Frictional resistance on one rear wheel f = $F_{total}/2$ = 5.61 N
$T_{min} = 2 \times t$
T_{min}= 3.78 N·m
Now we know the minimum amount of torque to move the vehicle and the maximum torque that can be applied to prevent slipping.

V. Selection of bicycle over tricycle

This become important whenever it becomes difficult to balance at low speed and specially when stopped.On a steep hill you can go as slow as you like without wobbling and take a rest by simply holding the brakes.

Also it provides better handling and safe riding while sloping down a slope and is more spacious than bicycle for various other applications.

VI. MATERIAL SELECTION

Table 5. Material Selection

Properties	***Weightage***	***Mild Steel***	***Aluminum Alloy 6061***
Strength	10	8	7
Corrosion Resistance	6	5	6
Ease of Manufacturing	6	6	6
Weldability*	5	5	4
Cost	8	8	6
Availability	6	6	4
Weight	10	6	9
Total	51	44	42

*w.r.t arc welding

VII. FRAME TYPE

There are two options either to choose Delta (two wheels at rear receiving power and one wheel at front) or Tadpole (one wheel at rear receiving power and two wheels at front).

Table 6. Body Selection

Criteria	Weightage	Delta	Tadpole
Stability	10	7	10
Utility	10	10	8
C.G. Height	10	7	10
Ease Of Designing	10	10	6
Steer Ability	10	9	8
Power Delivered	8	7	4
Cost	8	8	7
Total	66	58	53

VIII. 3D VIEW OF VEHICLE CHASSIS DESIGN

Figure 1. 3D Model of Delta Body Structure

IX. TRANSMISSION DESIGN

Figure 2. Transmission Design Testing

As the driver start pedaling main sprocket turns the sprocket on the intermediate axle. This sprocket turns the sprocket on the final axle with the same speed. On the final axle there is a large pulley, which rotate with the same speed. This large pulley rotates the small one which is mounted on gear reduction box through belt drive.

Pulley ratio = large pulley: small pulley = 1:2

So, small pulley rotates double the RPM of large pulley. Gear reduction box is of the ratio of 1:5. Output shaft of the gear reduction box is connected to the PMDC motor shaft. Thus, by this mechanism motor rotates at the speed 10 times of the speed of the rear axle.

Now, if vehicle runs at 10km/h = 166.67 m/min.
Perimeter of the rear wheel = $2\Pi r$ = 2.12 m.
So, speed of the vehicle in RPM = RPM of the rear axle = 77 rpm.
RPM of the PMDC motor shaft = 77 × 10 = 770 rpm.
Which produces more than 12V to charge the batteries during our testing.

Figure 3. Transmission Design

X. BRAKING

A. Braking force calculations

$v = u + a \times t$
For $v = 0$, $u = 8$ m/s, $t = 2$ s. Therefore, $a = -3.472$ m/s^2
Total Braking Force Required = 160 × 3.472 = 833.3N

This braking force is very easily handled by our front wheel shoe brake and rear axle band brake.

B. New innovative braking

The innovative braking system helps reducing the stopping distance to approximately 3 meters. It is mounted on the rear axle to control the movement of the rear wheel and also to avoid the overturning of the vehicle while descending the slope or during sudden braking of the vehicle. The rear brake consist of a cast iron disc mounted on the rear axle. It is provided with the band over its circumference and is based on the concept of band brake. The band is connected to the handle of the driver by a wire linkage.

Figure 4. Band Brake

XI. FRONT IMPACT ANALYSIS OF FRAME

FEA Results

Force estimation for loading conditions.

Estimation of Impact Force

For a perfectly inelastic collision, Energy Transferred by means of Dynamic Energy,

$$DE = \frac{0.5(m_1 m_2)(u_2 - u_1)^2}{(m_1 + m_2)}$$

Where, m_1 and m_2 are the two colliding masses with velocities u_2 and u_1 respectively. Since both m_1 and m_2 are two vehicles with similar masses and the vehicle m_2 is at rest,

$m_1 = m_2$ and $u_2 = 0$

Therefore, $DE = 0.25 \times m_1 \times u_1^2$

Now, F = DE/t

Where, t is impact time

$$F = \frac{0.25 \times m_1 \times u_1^2}{t}$$

Weight of vehicle = 80 kg (Assumed)

Weight of driver = 80 Kg

Total mass of vehicle along with driver = 80 + 80

= 160 Kg

Maximum Speed of Vehicle, u_1 = 8 m/sec

In most crashes t is of the order of 1s.

$$F = \frac{0.25 \times 160 \times 8^2}{1} = 2560N$$

Thus for design purposes force taken to be 2600N.

• Also, design output is for no plastic deformations.

The vehicle should remain in the elastic region.

• The Design Factor of Safety, was taken as 2. This relatively high value is taken to account for the uncertainty in the nature of forces.

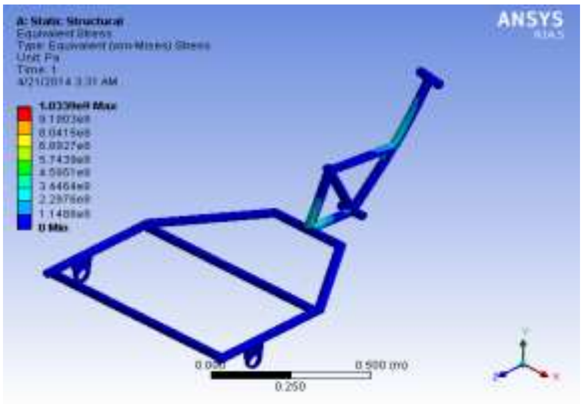

Figure 5. FEA Analysis of Vehicle body in ANSYS.

Front Impact Test

- Model Used: Full Model
- Loading: F= 2600N on Front Corner.
- Boundary Conditions:

1. Symmetry (Plane normal to Z axis)
2. Rear Corner Points All DOF=0.

XII. Wiring and Switching System

Here is the wiring and switching diagram showing connection between PMDC motor, battery, switches and ON-OFF key.

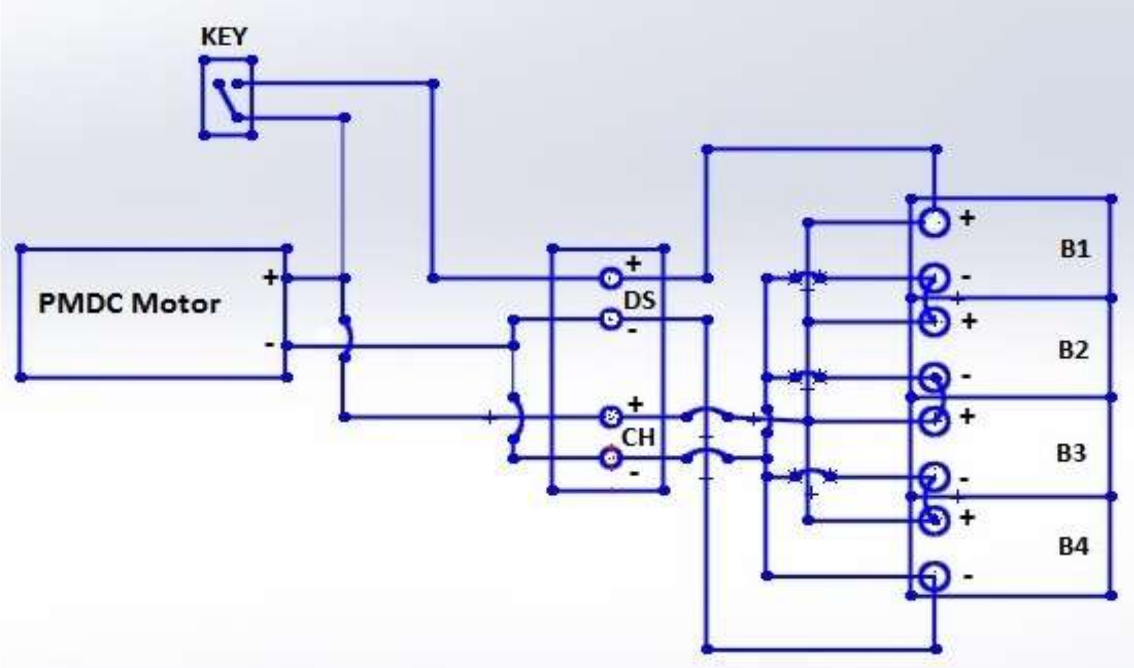

Figure 6. Wiring and Switch Connection Diagram

In Figure 6., B1,B2,B3,and B4 are Batteries; DS and CH are Dis-charging and Charging switches.

XIII. ABBREVIATION

DOF = Degree of Freedom
FEA = Finite Element Analysis
FOS = Factor of Safety
SLA = Sealed Lead Acid
PMDC = Permanent Magnet Direct Current
3D = 3 Dimensional

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