DESIGN AND ANALYSIS OF ONE WHEEL ELECTRIC VEHICLE

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ABSTRACT

A one wheel electric vehicle is similar to a unicycle. However, instead of sitting above the wheel, the rider sits within it. These vehicles seem to be a futuristic design, though they have been introduced in the beginning of the 19th century. Their unconventional design attracted many designers and engineers to develop it through the years. In recent times, various efforts have been made to develop this even further using modern technology and fabrication techniques. With the extensive use of vehicles dependent on conventional resources, there arises a clear need for vehicles that use alternative sources of energy. Electric vehicle drives offer a number of advantages over conventional internal combustion engines, especially in terms of higher energy efficiency, and decreased dependency upon oil. This thesis aims at achieving a fusion of both the above mentioned ideas. That is, the design and analysis of an electrically powered one wheel electric vehicle. An electrically powered one wheel electric vehicle would bring all the advantages of an electric vehicle whilst being a truly unconventional vehicle. This thesis gives a brief overview of a new one wheel electric vehicle. Design that aims at overcoming the deficits of ancient designs.

Keywords: *one wheel, electric, chassis, fabrication.*

1. INTRODUCTION

A one wheel electric vehicle is a one-wheeled single-track vehicle similar to a unicycle. However, instead of sitting above the wheel, the rider sits either within it or next to it. The wheel is a ring, usually driven by smaller wheels pressing against its inner rim.[1] Most are single-passenger vehicles, though multi-passenger models have been built.Hand-cranked and pedal-powered one wheel electric vehicle were built in the late 19th century; most built in the 20th century have been motorized. Some modern builders refer to these vehicles as monocycles, though that term is also sometimes used to describe motorized unicycles.[2] Today, one wheel electric vehicle are generally built and used for fun and entertainment purposes, though from the 1860s through to the 1930s, they were proposed for use as serious transportation.[3]

1.1 Types of one wheel electric vehicle

The research has shown here resulted in the first-of-its-kind electric hub motor driven one wheel electric vehicle l that can be used as a daily commuter vehicle. Having said that the research did not attempt to reinvent the one wheel vehicle, but focused on ergonomic design and fabrication process. [4]Thus the background depicted here focuses on existing models of one wheel vehicle powered by human power, I.C. engines and electric motors. Pedal powered one wheel vehicle is discussed briefly to understand the origin of monowheel. Further various I.C. engine powered models are reviewed for insight into the design trade off process inherent to the development of machine powered monowheel. Finally parallel research efforts are presented that focused on electric one wheeled single track vehicle.

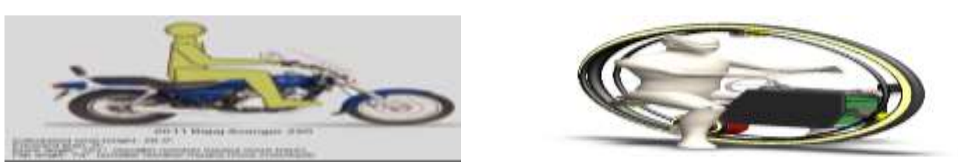

Fig -1: Comparative Ergonomics of two wheel and single wheel vehicle

2. AIM AND OBJECTIVES

The aim of this project is to make an optimized version of the battery operated one wheel electric battery operated vehicle in terms of its handling, environmental impact and compactness comparing to the earlier version of conventional one wheel vehicle design. By adding the attractive and innovative features such as for steering crank slotted mechanism, modifying chassis and seating arrangement.

3. DESIGN DISCRIPTION

The one wheel vehicle is designed so as to ensure that the rider stays in the desired upright position at all times i.e. even through steering across turns. This is achieved by allowing the outer wheel to tilt about the pivot point (vertical axis). So the pivot is a critical part of the monowheel design. Also, the outer frame has 3 PU rollers which keep the wheel assembly in place and allow it to rotate. Thus this is the main part of the entire one wheel vehicle design.

3.1 Design and Fabrication of Chassis

An important constrain taken during the design of the chassis was rider ergonomics. The dimensions of 95 percentile male (PERCY) were considered to come up with a design with comfortable driving posture. For easy assembly and improved serviceability proper clearance is provided for each component to be assembled on the chassis. Centre of gravity is a vital factor for stability of monowheel. For better stability the center of

Fig-2: Design of chassis

gravity of the chassis must be as low as possible. Tubular backbone type of frame is used in the design to reduce the number of members and keep the C.G. as low as possible. Another advantage of using the tubular backbone type of frame is the reduction in payload. The C.G. of the chassis is at 324.50mm from ground.

3.2 Design and Fabrication of Outer Frame

The one wheel vehicle is designed so as to ensure that the rider stays in the desired upright position at all times i.e. even through steering across turns.

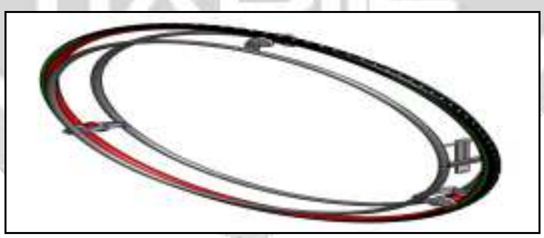

Fig-3: Design of outer wheel

This is achieved by allowing the outer wheel to tilt about the pivot point (vertical axis). So the pivot is a critical part of the one wheel vehicle design. Also, the outer frame has 3 PU rollers which keep the wheel assembly in place and allow it to rotate.

3.3 Roller Sub-Assembly

The main function of the rollers in the design is to successfully constrain the rim and allow it to rotate freely. These can be thought to be similar to the balls used in a deep grooved ball bearing which too keep the outer race constrained while allowing the rotary motion. The material of the roller must be such that there is sufficient friction between roller and rim. Angle of contact between the roller and rim is another important factor to be considered. If the area of the contact is too less it there will be slipping between the roller and rim and on the other hand if its value is too big it may result in jamming.

Fig- 4: Design of roller sub assembly

3.4 Tubular Ring

The upper roller mountings, the pivots, the rack mounting, and the hub motor mountings all are required to be securely welded into place so that the relative distances from each other do not change. This is the function of the two tubular rings. AISI 1018 steel of size 21.3mm*2.3mm was selected to make these rings. AISI 1018 steel is widely used relatively inexpensive and good weld ability. It has an ultimate tensile strength of 440 Mpa.

Fig- 5: Tabular Ring

3.5 Mass Balancing of one wheel electric vehicle

The one wheel electric vehicle has a single point contact with ground, if weights of all components are not properly distributed about vertical axis of the monowheel, the inner chassis of monowheel can get tilt at the maximum weight side. So mass balancing should properly done.

Fig- 6: Mass Balancing of one wheel electric vehicle

4. MATHEMATICAL DESIGN OF ONE WHEEL ELECTRIC VEHICLE:

4.1 Gyroscopic Effect

one wheel vehicle consists of electric hub motor driving the wheel. This motor which is rotates in the vertical plane same as the wheel, itself acts as a gyroscope for the one wheel vehicle.[6] Therefore if the weight of the one wheel vehicle goes to any one side of the driver, the monowheel can't fall due to the gyroscopic effect produced by the motor. This motor have 50 rpm per volt (manufacturing standard) for full charge of 48-53 V we have, rpm of the motor is 50 x 50 = 2500 rpm. Torque can be calculated as,

$$p = \frac{2\pi NT}{60},$$

$$1100 = \frac{2.\pi.2500.T}{60},$$

$$T = 4.2 \text{ N-M}$$

Maximum angle of tilt while turning is 20 degree as per concerned. For 20 degree of tilt, the radius of gyration will be given as follows, According to geometry, one wheel vehicle diameter is 5-ft, D_2=5ft = 56 inch = 60*0.0254 = 1.524 m

$$r = \frac{D2}{2} = \frac{1.524}{2} = 0.762$$

Radius of gyration (K) = 1.64 m, Therefore, total inertia of one wheel vehicle with weight of the wheel (8 kg),

$$I_w = m*K^2 = 8*1.64^2$$

$$I_w = 21.57 \text{ kg-m}^2$$

For motor(10 kg),

$$I_m = m*K^2 = 10*0.508^2$$

$$I_m = 2.58 \text{ kg-m}^2$$

For Gear Reduction ratio, Where D_2 = 60 inch, D_1=18 inch, ω_m= angular speed of motor, ω_w= angular speed of outer wheel

$$r = \frac{D2}{D1} = \frac{N1}{N2} = \frac{60}{18} = 3.33$$

N_1 = 2500 rpm, N_2 = 750.75 rpm

$$\omega_m = 3.33 * \omega_w$$

$$\omega_m = \frac{2\pi N}{60} = \frac{2.\pi.2500}{60}$$

$$= 261.8 \text{ rad/sec}$$

For a safe speed of 10 kmph during turning, angular velocity of precision,

$$\omega_p = \frac{v}{R} = \frac{10\left(\frac{5}{18}\right)}{0.762}$$

$$\omega_p = 3.64 \text{ rad/sec}$$

$$\omega_w = 78.52 \text{ rad/sec}$$

Therefore gyroscopic couple is given by,

$C = [I_w.\omega_w - I_m.\omega_m] * \omega_p$

C= [21.57*78.52 – 2.58*261.8]*3.64

C= 3714.22 N-m

This is the amount of reaction force which prevents falling of one wheel vehicle during turning.

5. DESIGN ANALYSIS OF SINGLE WHEEL VEHICLE

5.1 Design Analysis of chassis of one wheel vehicle

The most notable stress production onto the chassis would be found under loading. Considering the tube sizes that are affected by loads were changed, this was the primary focus for analysis. The maximum loading will be at points at the rear of members 1 and 2 where the rider sits. At these a load of 80kg is applied as shown in figure. On the points of members supporting the battery a force of 40kg is applied. With the forces known at each of the critical points, the analysis showed a maximum deflection of 0.948mm, which is an acceptable value. With a deflection of 0.94mm, there will not be an excessive deformation in the members. Also the stress produced is within the acceptable range.

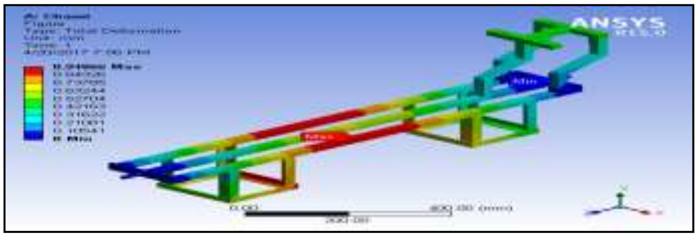

Fig- 7: Bending Stress Analysis of Chassis

5.2 Design Analysis of outer frame of one wheel vehicle

The most notable stress production onto the outer frame of one wheel vehicle would be found under loading. Considering the pipe sizes that are affected by loads were changed, this was the primary focus for analysis. The maximum loading will be at points pivot plates at front and back of chassis. At these a load of 150kg is applied as shown in figure. On the points of members supporting the battery a force of 28kg is applied. With the forces known at each of the critical points, the analysis showed a maximum Stress of 2.1302 Pa, which is an acceptable value. With a deflection of 3mm, there will not be an excessive deformation in the members. Also the stress produced is within the acceptable range.

Fig- 8: Bending Stress Analysis of Chassis

6. FUTURE SCOPE:

By changing Design parameter comfort can be increased. As per the requirements design can be modified and made compact, By increasing the safety parameters speed can be increased and control, Hybrid types of one wheel vehicle can be made which can work both on battery and solar power.

7. CONCLUSION

All parts of the one wheel vehicle are placed inside the wheel- motor, power source and the control system. The driver has to maintain its upright state when it is not moving or is going forward. The design consists of a small wheel at the bottom and a two part body with a hinge in the middle. The wheel is equipped with a solid rubber tyre, the driving motor and guides for rollers. Although a full mechanical model of the vehicle was built we mainly focused on the problem of maintaining its upright position when moving and in stable position. one wheel vehicle can handle inclines up to 25 degrees. In all uphill, at low constant speed maintained. Monocycles are statically unstable in the transverse direction. Attempts at adding stabilizing wheels or skids proved largely unsuccessful since these devices cause the cycle to turn quickly and unexpectedly if they touch the ground while the wheel is in motion. The tendency worsens at higher speeds. The monocycle is assumed to have three degrees of freedom, namely, lateral, rotational, and translational. The maximum possible speed can be obtained up to 25 kmph.

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