DESIGN AND FABRICATION OF HUMAN-ELECTRIC HYBRID POWER TRI-CYCLE

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Abstract. “EFFI-CYCLE” derived from Efficient-Cycle promotes reducing dependency on fossil fuels for domestic transport application. The objective of this paper is to conceive, design and fabricate a three-wheel configuration (tad-pole design) vehicle powered by human-electric hybrid power and capable of seating two passengers catering to the day to day mobility needs. PTC Creo 3.0 software is used for geometric modelling of the vehicle’s frame. To ensure the safety of the design the model is then imported into ANSYS V16.2 for impact analyses. Results in terms of deformation, strain and von Mises stresses are plotted. After successfully completing the design and simulation of the frame and other components it is then fabricated in the college’s (S R Engineering College, Warangal) workshop.

Keywords: Efficycle, Finite Element Analysis, SAE, Hybrid Vehicle, Electric Tricycle.

1. Introduction

The modern world today faces a huge crisis in fuel energy consumption and conservation. With ever increasing need for fuel and dependency of transportation systems on it, scientists predict that by 2040, the world’s fuel reserves would be reduced to 20% of their current status [1]. This will lead to a price hike for fuels. So, the need of the hour is to switch over to a new form of transport that reduces the current strain on the natural resources and aims at leading in an era of sustainable development.

A large number of studies [2-5] depicts their concern over congestion and pollution associated with the use of a motor vehicle for personal transport. This paper aims to design a vehicle that could be a viable alternative to cars for short distance journeys. This designed vehicle is powered by a hybrid human-electric drive system. The combined human and electric powered vehicle is the vehicle which is driven by human muscular power as well as electric power. The working principle adopts the synergy of bicycle and electric vehicle technology. This is a three-wheeled vehicle, driven by a maximum of two members with side by side seating arrangement. The vehicle is equipped with a BLDC 1.4 HP electric motor retrofitted at the rear side, 4 sealed lead acid battery (each of 12 Volts) and chain drive used for electric power transmission. Besides this, two manual-pedaling systems also provided for the human power transmission based on the principle of bicycle. Whenever required the mode of driving (manual to electric and vice-versa) can be altered. The tadpole type configuration is used for this vehicle in which
two wheels are mounted in front side and one wheel in the back side of the vehicle. The vehicle has an Ackermann type steering system handled by one driver (Right-hand side). Disc brakes with sliding calipers in direct connection are provided in all the three wheels for proper and effective braking.

For a better understanding of the complicacies pertained in fabrication a prototype is made. From this paradigm, after doing some modification a hand-sketch is drawn proceeded by a CAD model generation. The roll cage material selection was carried out with an aim to optimize strength, weight and cost. A preliminary study for the frame’s structural integrity is carried out, using finite element analysis, prior to its fabrication. The key parameters taken under consideration were safety, ergonomics, weight reduction and cost of manufacturing the chassis.

2. Design Procedure

The dimensions of the vehicle are first assumed considering the constraints and dimensions based on the rulebook of SAE. After assuming the dimensions, the focus was given to make the vehicle ergonomic for an average adult person. Then the vehicle is designed on a CAD Package PTC Creo 3.0. The structural integrity of the vehicle is tested by using Finite Element Analysis software ANSYS V16.2. To ensure the safety the design of roll cage/frame is modified and then the design is finalized. During manufacturing various parameters like serviceability, craftsmanship and cost reduction were considered. In order to make the vehicle more attractive and convincing, its aesthetic considerations like appearance were also given utmost importance. The geometric model of the vehicle is shown in figure 1 (a)-(d). Vehicle dimensions and different component specifications are given below in Table 1.

![Figure 1(a): Isometric view of the vehicle](image1)

![Figure 1(b): Front view of the vehicle](image2)

![Figure 1(c): Side view of the vehicle](image3)

![Figure 1(d): Top view of the vehicle.](image4)

*Figure 1 (a)-(d): Three dimensional CAD model of the hybrid tri-cycle vehicle.*
### Table 1. Vehicle dimensions and component specifications

| Component                      | Specifications / Dimensions |
|-------------------------------|----------------------------|
| Motor                         | BLDC 1.4 HP, 500 RPM 48 Volts motor |
| Frame material                | AISI 1018                   |
| Frame material dimension      | OD- 31.75 mm, ID- 28.55 mm, Thickness- 1.6 mm |
| Weight of drivers (two members) | 120-180 kg                  |
| Wheel configuration           | Front - 2, Rear - 1         |
| Steering                      | Ackermann with drag link    |
| Turning Radius                | 3.4 m (analytical calculation) |
| Turning angle                 | 45°                         |
| Braking                       | Mechanical Disc Brake on all the wheels |
| Dimension                     | Length - 2368 mm, Height - 1404.9 mm, Wheelbase - 1524 mm, Ground clearance - 152.4 mm |

3. **Frame**

The frame was designed considering better aerodynamics and comfortable base for the riders. Additional aspects of battery mounting, suspension and seating arrangements were also designed as per the Efficycle rulebook [6], along with this arrangement for top covering is also been designed for the shelter of riders. The material used for the frame is AISI 1018 having a circular cross-section. The material composition and its properties are given in Table 2 and 3.

### Table 2. Frame material (AISI 1018) composition

| Element                  | Carbon, C | Iron, Fe | Manganese, Mn | Phosphorous, P | Sulfur, S |
|--------------------------|-----------|----------|---------------|----------------|-----------|
| Content (%)              | 0.14 - 0.20 % | 98.81 - 99.26 % | 0.60 - 0.90 % | ≤ 0.040 %      | ≤ 0.050 % |

### Table 3. Mechanical Properties of AISI 1018

| Property                      | Value       |
|-------------------------------|-------------|
| Hardness, Brinell             | 126         |
| Tensile Strength, Ultimate    | 440 MPa     |
| Tensile Strength, Yield       | 365 MPa     |
| Modulus of Elasticity         | 205 GPa     |
| Bulk Modulus                  | 140 GPa     |
| Poissons Ratio                | 0.290       |
| Shear Modulus                 | 80.0 GPa    |
| Density                       | 7870 kg/m³  |

4. **Finite element analysis of vehicle-frame**

The frontal, side and rollover impacts analysis were performed on ANSYS 16.2. The CAD model and the actual fabricated vehicle frame/roll cage of the hybrid tri-cycle is shown in figure 2(a) – (b).
5. Frontal impact analysis

Assumption & Considerations:
In pretext to calculate frontal impact, a top speed of 35 kmph to final zero velocity is assumed to be attained by the vehicle in 0.6 sec. The weight of the vehicle is considered as 150 kg and two drivers each of weight 90 kg. The vehicle might be subjected to any impact, inattentively or deliberately. The vehicle is expected to sustain through the impact, so it is need of the hour to find out impact forces and, perform impact analysis.

Calculation of Impact Forces:
Total mass \( m \) = 150 + 90 + 90 = 330 kg, Time \( T \) = 0.6 sec, Initial velocity \( u \) = 35 km/hr = 9.723 m/s, Final velocity \( v \) = 0 km/hr. Also, Front Impact Force \( F = m \frac{dV}{dT} = 330 \times \frac{9.723}{0.6}, F = 5348.16 \) N. A maximum force of 5348.16 N is considered for front impact

Analysis Results:
The simulation is performed on ANSYS Workbench platform. The model is meshed with tetrahedral elements. Convergence study is also done to finalize the finite element mesh size. Result plots in terms of total deformation, von Mises stress, factor of safety and equivalent strain are shown in the figure 3 (a)-(d). Their quantification is as follows: Maximum Deformation = 4.341 mm, Maximum stress = 146.37 MPa, Safety Factor = Yield strength / Max stress = 365/146.37 = 2.49, Total Strain = 0.00088327. The above values taken from figure 3 (a) – (d) are well within the permissible range that ensure safe design.

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Figure 2(a) – (b): CAD model and the actual fabricated vehicle frame/roll cage of the hybrid tricycle.

Figure 3(a): Total deformation plot. Figure 3(b): Equivalent von-Mises stress distribution.
6. Side impact analysis

Assumption & Considerations:
Assumptions are similar to that of front impact except for the time taken to stop by the vehicle after a collision with the wall is assumed to be 1s.

Calculation of Impact Forces:
Total mass \( m \) = 150 + 90 + 90 = 330 kg
Time \( T \) = 1s
Initial velocity \( u \) = 35 km/hr = 9.723 m/s, Final velocity \( v \) = 0 m/s
Also, Side Impact Force, \( F = m \times \frac{dV}{dT} = 330 \times \frac{9.723}{1}, F = 3208.59 \text{ N} \)

Analysis Results:
A maximum force of 3208.59 N is considered for side impact. Result plots in terms of total deformation, von Mises stress, factor of safety and equivalent strain are shown in the figure 4 (a)-(d). Their quantification is as follows: Maximum deformation = 0.5236 mm, Maximum stress = 29.207 MPa, Safety factor = Yield strength/Maximum stress, = 365/29.207 = 12.5, Total strain = 0.0001619.
7. Rollover analysis

Assumption & Considerations:
In pretext to calculate roll-over impact, a top speed of 35 kmph and final velocity as zero is assumed to be attained by vehicle in 6 sec. The weight of the vehicle is considered as 150 kg and two drivers each of weight 90 kg.

Calculation of Impact Forces:
Mass of trike = 150 kg
Mass of drivers = 90 + 90 = 180 kg
Total Mass = 330 kg

\[ F = \left( \frac{N \times w}{2} \times h \right) \]
\[ F = \frac{330 \times 9.81 \times 4.8}{2} \]
\[ F = 1438.8 \text{ N} \]

Analysis Results:
Result plots in terms of total deformation, von Mises stress, factor of safety and equivalent strain are shown in the figure 5 (a)-(d). Their quantification is as follows: Total Deformation = 3.007 mm, Maximum Stress = 70.205 MPa, Safety factor = Yield Strength / Maximum stress = 365 / 70.205 = 5.19, Total Strain = 0.000435

8. Safety features of the vehicle

The drivers are provided with seat belts to overcome the hazards of collision. All the electrical wires are well insulated, and the battery case is made leak proof. Drivers are also equipped with a safety helmet, knee pads, gloves, side mirrors for rear view etc. Always safety is considered over comfort. Seats are provided with synthetic foam material so that drivers could feel comfortable. Handling of the vehicle is
easy as it is provided with good steering mechanism. The vehicle is made attractive using paints. The design is also unique that makes it appealing.

9. Conclusion
The initiative towards EFFICYCLE was taken with the aim to have hands-on experience in designing a Hybrid Human-Electric Tri-Cycle keeping in view the ease of manufacturing and economy. The design was made by the use of CAD software PTC Creo 3.0 and the design was analyzed by FEM analysis software ANSYS V16.2. The simplicity of design and Hybrid drive train were the key parameters in the vehicle design. This design and fabrication of Efficycle will create awareness towards environment-friendly mobility solution.

Acknowledgement
A special thanks to Prof V Mahesh (Principal, SREC), Prof P Sammaiah (HOD, ME, SREC) and college management for providing the computational laboratory and workshop facilities to carry out this work. Their encouragement and support are appreciably acknowledged.

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