DEVELOPMENT OF AN EFFICIENT HYBRID TRICYCLE

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Abstract

Tricycle rickshaw is a very cheap means of short distance transportation both in city and in rural areas. Tricycle rickshaw is generally propelled by human energy. A study has been performed with the existing model and design of tricycle rickshaws. It has been observed that traditional rickshaws use age-old technology, poor mechanical design and hence non-ergonomic in maneuverability. An effort has been directed to design a lightweight, high strength, and ergonomic both human pulled and electric powered hybrid rickshaws. The proposed model is powered with 400 W, 24 V DC permanent magnet motor, in addition to human power. Both the options may work independently as well as in parallel hybrid mode. The structural design of the rickshaw has been analyzed using Autodesk inventor software to see the effect of different unbalanced stresses. It was observed that overall structural design was safe. The rear part of the tricycle was less effected (0.0001249 Pa) whereas front link connects to front wheel is more likely to affect ($1.4438e^{8}$) by different unbalanced impacts tests.

Key words: Hybrid, Tricycle, Efficient, Electric

1. Introduction

About 80 lakhs rickshaws ply all over India in both rural and urban areas. Therefore, rickshaws provide livelihood of eight millions very poor rickshaw pullers families in India [1]. It has been observed that most of these rickshaws are of age-old design, and consequently design and manufacturing are not in an organized sector. Therefore, the present study is concerned with design and development of a hybrid human, mechanical, and electric powered tricycle for short city trips as an alternative mode of transport. Conventional human powered tricycles are amply available in different cities in India. However, they are not ergonomically designed with respect to rickshaw puller and passengers comfort and maneuverability. There are different literatures available both on national and international levels on improved tricycle design development in manual, mechanically assisted and electric hybrid mode. However, for improved design in electric hybrid mode, the success story is very limited mostly because of high cost involved to economically and socially poor rickshaw pullers, unwillingness of illiterate rickshaw puller to adopt new technology, non-availability of easy after sell services and most importantly inadequate quality assurances from inventors as well as manufacturers. However, researchers are putting effort to address the inherent inefficient mechanical design of conventional rickshaw. Few of the national research and development works are cited below.

Central Mechanical Engineering Research Institute (CSIR-CMERI), Kolkata had carried out research and development works on prototype development of an improved solar powered hybrid rickshaw. Solar panel charging system was based on some recognized charging station. The design had shock absorbers for a comfortable ride, headlamp for night riding. Moreover, it had (240 -350)W, 36VDC motor independently housed with front wheel hub of the SOLECKSHAW with a regenerative capability. The rear wheels are manually powered by the rickshaw puller. The electric mode riding lessen the effort required to drive the rickshaw. Brakes were provided to all three wheels, maximum payload 200 kg and speed 15 km/h [2]. However, in-spite of all advantages, cost, and non-availability of solar charging system easily may be a prohibiting factor for poor and illiterate rickshaw pullers for popularization this model. Hickmen studied on India tricycle rickshaws for design improvement. He observed that rickshaws are not designed for driver comfort and safety. Traditional rickshaws have single speed ratio that causes driver to put high effort for starting or hill climbing or in bad road condition. Moreover, Indian rickshaw pullers are poor and undernourished. These studies discussed different techniqueslike addition of an electric drive, multiple gear ratio chain and sprocket, regenerative capability, use of a flywheel or spring for energy conservation and delivery as per load, etc., had been discussed [3]. The present price of a conventional rickshaw is nearly Rs.15000.00 whereas an electric assisted one will still cost Rs.35000.00 to Rs.40000.00. Therefore, reduction of cost is of utmost important before any new design of rickshaw is available to the poor rickshaw pullers in India.

2. Literature review

Alametal.,studied the significance of aerodynamicdesign and comfortable riding of human powered tricycle. Wind tunnel testing was reported to find out the key characteristics of this human powered vehicle. The magnitude of aerodynamic drag significantly varied with the test vehicles physical profiles. They observed that the human powered vehicle manufacturers did not necessarily took into account the importance of aerodynamics in conventional tricycle design. This study showed a significant reduction in aerodynamic drag compared in an appropriately designed vehicle (aerodynamically) compared to a conventional vehicle. The seating position in such vehicle plays an important role. The reclining position further backward allowed an additional reduction of frontal area thus it lowered net drag force. Additionally, the reclining position further backward shifting may provide better physical advantages for endurance as indicated by observations at a race event. As expected, component add-ons and their positions generally increased drag more at low speeds than at high speeds. Wheels covers reduced total drag on the vehicle than uncovered wheel one [4]. Yang et al., studied an energy management system with an electronic gearshift and regenerative braking for a directly driven electric scooter. This was presented to improve the gross efficiency and driving range of an electric scooter. It was driven directly by a four-phase axial-flux DC brushless in wheel hub motor. The integration of stator windings, batteries, ultra-capacitors, and a digital controller constituted an energy management system, which featured smooth electronic gear shifting and regenerative braking. The gross efficiency of the experimental scooter was improved in the drivable range by 20% with respect to that without regenerative braking. The battery-to-wheel efficiency was also above 70% for both low- and high-speed gears [5]. Asaei and Habibidoost studied design, simulation, and conversion of a normal motorcycle into a Hybrid Electric Motorcycle (HEM). At first, a simple model was designed and simulated with ADVISOR2002. Then, the controller schematic and its optimized control strategy were described. A 125 cc ICE motorcycle was selected and converted into a HEM. A brushless DC (BLDC) motor assembled in the front wheel and a normal internal combustion engine in the rear wheel propelled the motorcycle. The nominal powers were 6.6 kW and 500W for the ICE and BLDC respectively. The original motorcycle had a Continuous Variable Transmission (CVT). This was the best choice for a HEM power transmission because it could operate in the automatic handling mode and has high efficiency. Moreover, by using the CVT, the ICE could be started while motorcycle was running. Finally, three operating modes of HEM, two-implemented energy control strategies, and HEM engine control system by servomotors, and LCD display were explained [6].

There is a steady increase in the emission of greenhouse gases in the earth's atmosphere that is creating changes in the global climate. A third of GHG emissions in the world originate from the combustion of fossil fuels in internal combustion engines that is reflected in recent studies [7]. Therefore, the European commission in Europe has set a target of reducing CO_2 emissions from new vehicles to an average of 125 g/km by 2015 with a longer aim of 100 g/km by 2020 [8]. The primary concept behind a hybrid vehicle is to use stored or secondary energy source in the vehicle to supplement the primary energy converter for improved overall energy efficiency. The primary energy converter operates at a constant power output that is much more efficient than the dynamic operation needed to match vehicle needs gains in fuel efficiency are the driver for this technology. The secondary energy source supplements the primary energy converter or stores the excess energy. Additional benefits of the hybrid design include: (1)A smaller primary energy converter that costs less, (2) Reduced emissions resulting from substantially eliminating dynamic modes of internal combustion engine (ICE) operation, and (3) An electric power train that allows for other advantages such as fewer moving parts and regenerative braking. It is generally recognized that the hybrid with its electric power train is compatible with the use of fuel cells for the primary energy converter [9].

The ability of the hybrid technology to reduce the size of the fuel cell stack as a primary energy converter will be crucial to ease the costs of fuel cell vehicles during initial stages of commercialization. The plug-in hybrid is a modified version of a hybrid vehicle with a secondary power source larger than in a standard hybrid that can be recharged using grid electricity. By replacing vehicular fuel consumption with grid power, advantages of zero point-source emissions and displacement of petroleum fuel consumption can be realized. In this configuration, the hybrid vehicle functions more like an electric car with ICE (or fuel cell) backup to provide increased range upon demand [10]. The fuel cell hybrid provides an additional degree of freedom on this plug-in option; namely, the grid power could be used to recharge batteries (the secondary power source) or to hydrolyze water to hydrogen for use with the fuel cell (primary energy converter). As the costs of fuel cells decrease, the likelihood of transforming large sectors of the petroleum-based transportation infrastructure to a hydrogen-based infrastructure increases. These trends are motivated by the potential of fuel cells to reduce vehicle-operating cost. Table 1 summarizes typical vehicle operating costs, and as illustrated by these itemized costs, fuel costs are minor in comparison to those costs related to the vehicle, its maintenance, and the insurance costs to repair damaged vehicles.

Table 1: Typical operating costs for vehicle

Parameters	Vehicle operating Average ($/mile) cost (%)	Average cost (%)
Depreciation	22.5–31.8	49.2
Insurance	6.9–10.5	14.3
Financing	4.8–8.3	12.3
Fuel	4.5–6.9	10.9
Maintenance, oil, tires	4.7–5.3	9.1
License and registration	1.4 –3.2	4.2

Ranges include low-end cost of mid-sized car and upper-end costs for luxury car and SUV [11]

In many Asian and South American cities, petrol powered scooters are popular means of transport due to limited space requirement caused by large population density in cities. In these areas of the world, scooters are a more affordable option than automobiles [12, 13]. However, the infrastructure in urban cities does not support an extensive transport network as well as parking spaces. Scooters are therefore more popular as they can be maneuvered around traffic more easily than larger vehicles, especially in congested roads and take less parking space. Scooters are different from cars as they are not normally equipped with advanced engine management and catalytic converter systems to reduce harmful emissions. It was shown by Sripakagorn and Limwuthigraijirat [14] that conventional petrol motorcycles emit 95% more pollutants than larger sport utility vehicles due to the lack of installed emission control technologies. Recently, Zero Emission Vehicles (ZEVs) have received a lot of attention worldwide. For example, battery electric vehicles (BEVs) and hydrogen fuel cell vehicles (HFCVs) are seen a possible solution to tackling GHG emission. Major global automotive manufacturers such as Honda (FCX Clarity), Nissan(FCVX-trail) and Daimler-Chrysler have invested significant amounts on R and D for fuel cell vehicles.

Norcliffe [15] studied that working tricycles in China's cities serve as the platform for millions of micro-enterprises. A study was undertaken by Kendallaet al., on the hydrogen fuel cell hybrid vehicles which were introduced in Birmingham Campus [16].

Based on above literatures the principal objectives of present studies are: (1) Development of an ergonomic and improved mechanical design tricycle, particularly for rickshaw puller and passenger in general. (2) Development of electric powered tricycle with 400 W 24VDC motor to supplement motive power for riding in hybrid mode. Both the rickshaw puller and passenger seat height from the ground will be lowered to most comfort ride. Therefore, the efficient and eco-friendly tricycle is propelled without using a fossil fuel. To build a tricycle that is aerodynamic, highly engineered for operational aspects, safe and ergonomically designed to utilize lesser effort and of course must have higher top speed than the counterpart already in place. Moreover, the innovation is proposed to use a fraction rider and rickshaw weight to assist partially pulling effort of rickshaw puller during operation. The new idea if practical implemented might substantially reduce drudgery and hardship of poor rickshaw pullers.

3. Materials and methods

The present design of an improved electric tricycle is an attempt to explore the inherent shortcomings of conventional tricycle (rickshaw). This is a developmental design of existing rickshaw available in road. Somestandard parts of a commercially available rickshaw and bicycle are selected as standard components requirement. They include chain and sprocket, freewheel, wheel and axle, etc. Standard motorcycle and scooter ball bearings were selected instead of conventional rickshaw bearing to get less frictional resistance in shafts. Material selection of the chassis plays crucial part in providing the desired strength, endurance, safety and reliability to the vehicle. Two main materials under consideration are: AISI 1018 and 4130 Chromalloy steel. The strategy behind selecting the material for roll cage was to achieve maximum welding area, good bending stiffness, minimum weight and maximum strength for the pipes. So, after market analysis on cost, availability and properties of these two alloys, AISI 1018 was used of the following dimensions:Outer Diameter: 25.6mmWall Thickness: 3.50 mm .The frame is provided with two independent rear suspensions adopted from motorcycle. These suspensions are supposed to provide comfortable ride to the passengers and riders. The front wheel suspension is a fork type one. The front and rear subassemblies of the designed tricycle is pivoted at the center with two swing arms. These swings arms are providedto effectivelyabsorb road vibration through shock absorbers.The conventional handle steering of rickshaw is replaced with a PVC based steering wheel for better control and drivability. Steering effort is transferred to the front wheel through low cost lightweightcable system. The adjustable driver seats with arm and head rest have been provided both for ergonomy and comfort. Unlike conventional rickshaw, an innovative differential is provided that totally eliminated pulling towards one side. The 3D CAD of the hybrid tricycle is shown in Fig.1 and its frame is presented in Fig.2.

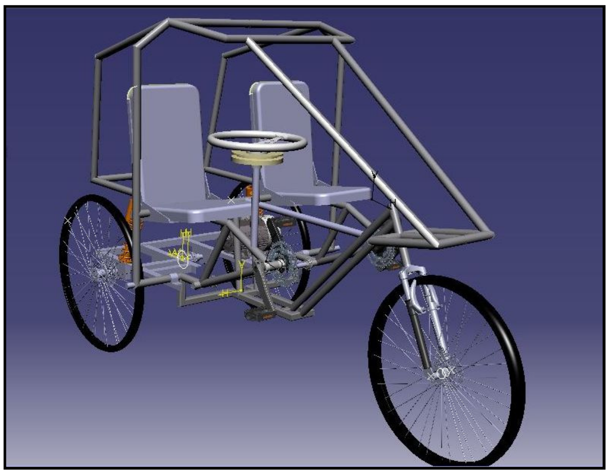

Figure1 CAD 3D model of the hybrid tricycle

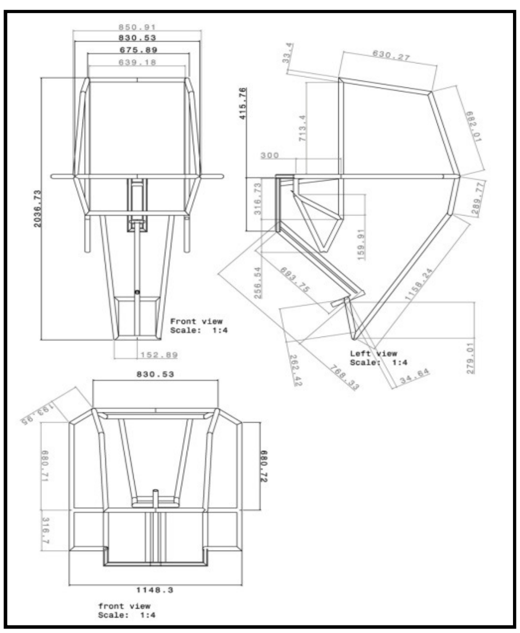

Figure 2 Frame of the hybrid tricycle

4.Results and discussions

The layout of the hybridelectrical tricycleis given in Fig.3. It is clear that different combinations of free wheels are used for fabrication of the transmission. The Fig.4 represents front impact test (***Autodesk Inventor***) of the proposed design of the tricycle frame. Stress level at different parts of the frame is obtained considering the various possible impact tests of tri-cycle. Minimum stress is given by blue color (0.00012494 Pa) and maximum rating is given by red color (9.44487e^7 Pa). It is clear from this figure that rear frame of the tricycle is much safer during front impact. Likewise, intermediate parts are at averagely stressed. Fig.5 shows variation of load distribution during front bump testing. It is also clear that most vulnerable part of the frame is yellow and red color subassembly (middle parts) and variation of stress (0.00029-1.4438e^8)Pa.

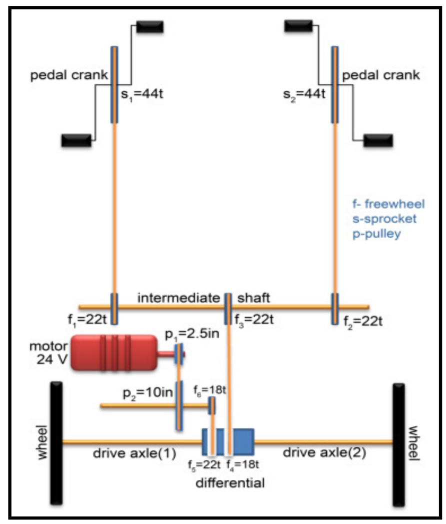

Figure 3 Layout of electric hybrid tricycle

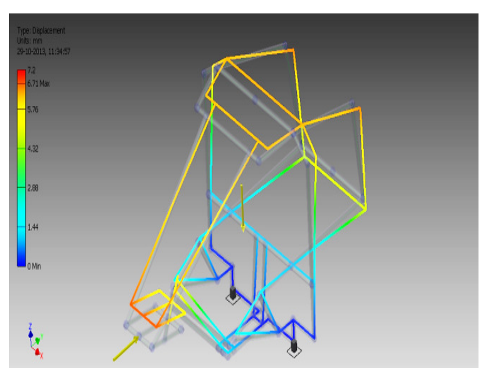

Figure4 Front impact test

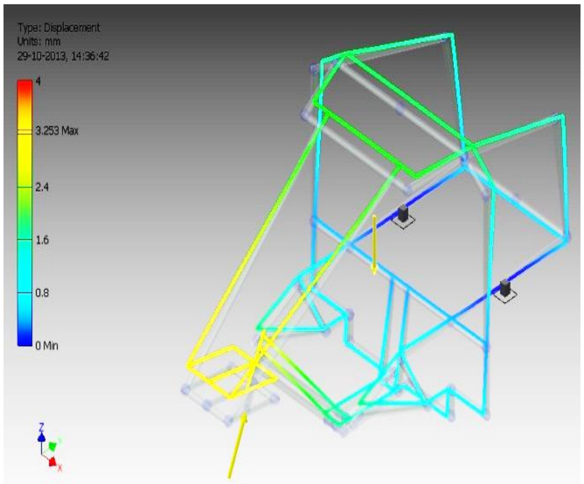

Figure5Front bump test

Figure 6 shows the variation of load during rear bump testing. Joints of middle subassembly frame are mostly vulnerable for front bump.

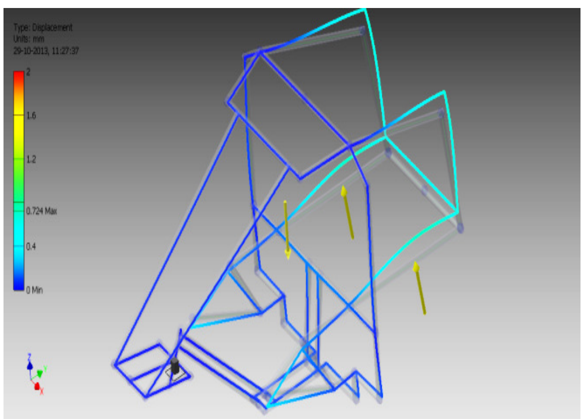

Figure 6 Rear bump test

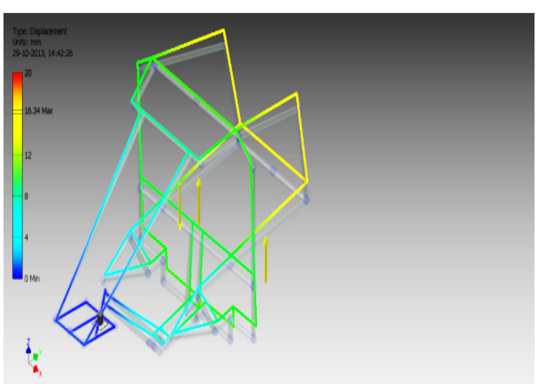

Figure 7 Rear impact test

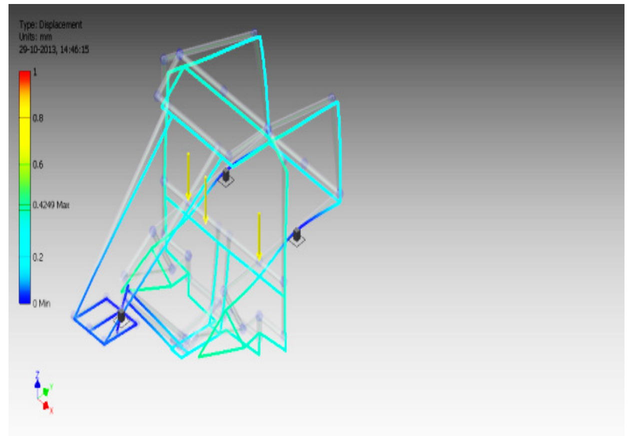

Figure 8 General loading

Figure 7 shows variation of stress during rear impact and Figure 8 shows stress when vehicle is balanced. Figure 9 shows roll over test for the frame of the tricycle. It is clear that the central antiroll bar is mostly vulnerable for rolling test.

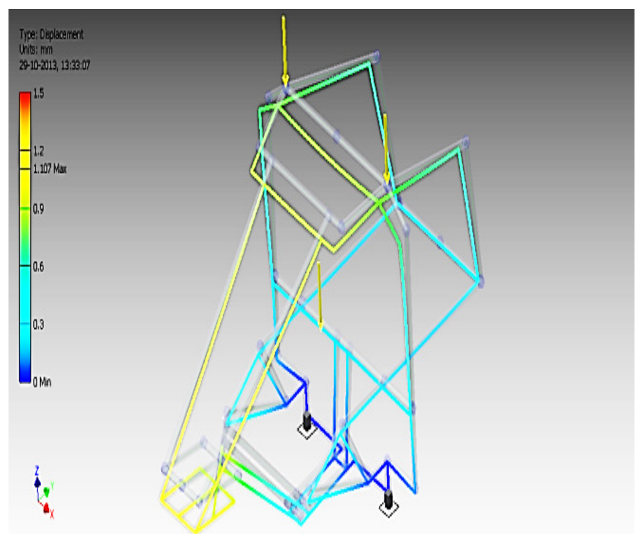

Figure 9 Roll over test

Sufficient safety features are provided to the riders. They include independent seat belts for each rider, integrated structure, and Roll Cage to protect riders in case of accident, mudguards on all three wheels and chain tubes for the part near riders' legs.

The design of tricycle is fully incorporated with ergonomics for comfort of rider and energy optimization. They are summarized as follows: (Fig.10).

- Biomechanically optimized sitting position and knee angle is (80-89 °).
- Adjustable seat to suit both tall and short person.
- Ease of entry and exit due to less width.
- Seat frame design is to provide easy and comfortable ride to both members.
- Easy to use seat belts incorporated to increase the safety of driver and passenger.
- Braking system applied on all three wheels to provide accessible and easy control and stopping of the vehicle.
- Easy to use steering system to facilitate better control of vehicle at turns and corners at various speeds.
- Aerodynamic frame and roll-cage design to reduce drag and increase efficiency of the vehicle.
- Efficient and cheap differential system to provide proper control at sharp corners even at high speeds.
- Use of dual-spring shock absorbers for both rear wheels and fork suspension for front wheel coupled with swing arm to provide smooth ride even at rough terrains.
- Unobstructed vision to increase better maneuverability.
- Weather guard cover to protect driver,rider,motor,batteries and other components from various weather conditions are incorporated.
- No requirement of fossil fuels and no release of pollutants during running, thus making the vehicle a Zero Emmission Vehicle.
- Low maintenance and production requirement due to use of common but sturdy rickshaw components.

Figure 10 Prototype of the trike after fabrication

5.Conclusions

The present design uses a permanent magnet motor (PMDC)and not any internal combustion engine which creates the pollution by using fossil fuel. Therefore, the propulsion of this hybrid tri-cyclewould protect ecosystem and environment from ever-increasing pollution. Moreover, this design usesdual spring shock absorbers that are safefor drivers when the bumping takes place in bad road condition. Additionally, the innovative differential is used so that the power transmits equally to both wheels avoiding the biasing and banking angle (pulling the tricycle in one side).Old and special persons (PWD) may use the vehicle, as they get tired in normal conventional cycles. The hybrid design uses a motor powered by batteries that may be charged easily and regularly by simple plug in method. So it isecofriendly and easy to use.The rear part of the tricycle is less effected (0.0001249 Pa) whereas front link connects to front wheel is more likely to affect ($1.4438e^{8}$ Pa) from the impact studies.

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