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Design and development of intelligent co-dependent hybrid human-electric velomobiles

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Abstract:

City roads in India have become unusable during rush hours due to rapid increase of car users, proliferation of low occupancy vehicles and lack of usable mass transit system. This cause's excess unhealthy air quality due to emission from vehicles mostly operated using hydrocarbon-based fuels and forces commuters to breathe the polluted air for increasing durations due to daily traffic jams. Most of the mass transit systems in Indian cities are limited in reach, frequency and comfort. Unless extremely fortunate a typical commute requires complementing mass transit vehicles with other options such as bicycles, (auto)-rickshaw, walking etc. thus contributing to, and suffering from congestion and associated evils. This has led to widespread obesity and related lifestyle diseases. This project aims to develop a modular electricity-assisted human-powered mass transit system which should address at once many of the problems mentioned above.

Keywords: Velomobile, Hybrid, Intelligent, Tadpole-trike.

INTRODUCTION:

DEFINITION

A velomobile or bicycle car is defined as a human powered vehicle (HPV) equipped with a partially or fully enclosed fairing. This fairing provides both improved aerodynamic properties and protection for the user from fluctuating weather conditions and collisions. These vehicles allow for users to ride in all-weather conditions with improved comfort over a recumbent trike, recumbent bicycle, or standard bicycle. Velomobiles can also be adapted to allow for increased storage over that which is found in any other type of bicycle. This allows for a user to be able to commute daily, to and from work, with all their necessary supplies without relying upon an automobile. However, as more weight is added to the velomobile it may become difficult for a user to surmount simple obstacles, such as hills or steep driveways. For this reason, small motor assists can be incorporated into the design of the velomobile to assist a user in physically demanding situations.

DESIGN CONSIDERATIONS

Human powered hybrid vehicles present the new milestone in the realm of "Green Technology". The vehicle that is cheap to buy, cheap to run and can be used from a track racer to a grocery seller everybody contributing towards a green environment. In literature, there are two available designs of vehicle:

Delta:

The delta type of trike has one wheel in the front and two wheels in the rear. These types of trike can give its best in steering as it can have a zero turning radius. The power to the rear wheels of the delta trike ensures no slipping during cornering.

Tadpole:

The tadpole type of trike has two wheels in the front and one wheel in the rear. Both the trikes have their pros and cons. But tadpole configuration always has certain advantages over the delta configuration in almost every field. Being a rear wheel driven configuration, the tadpole configuration will have all the tractive effort available from its share of the weight. Also because of the major weight on the front side of the vehicle there is much grip available for both steering and braking. Electrically assisted tadpole trikes are much more stable when compared during cornering. Delta trikes on the other hand has less front weightage due to which it can't give its best in both braking and steering. Electrically assisted delta trikes are more unstable. After analysing both the designs it is preferred to choose tadpole over the delta.

Literature survey:

Literature survey on design of human-electric hybrid velomobile:

S. Mil'shtein et al. (2008) developed a trike incorporating solar panels, electric motor and pedals. Solar panels used measures panel measuring 1.92x0.92m at peak operation produces 36v with 6A

current. Maximum Power Point Tracker was also been incorporated. Use of MPPT (Maximum Power Point Tracker) led to increase in efficiency. Thus trike was fabricated with a combination of solar electrical energy with linear pedalling.

Rickey M. Horwitz (2010) calibrated Pros and cons of delta and tadpole trikes are studied. Types of steering used, Front Steering vs. Rear Steering and Trike end design has been studied. The final inference we derived was Tadpole trike has better rolling and lateral stability. Tadpole trike has better efficiency than delta trike.

Rishabh Jain et al. (2015) developed technique of eliminating sprockets in three wheeler, tadpole configured hybrid cycle. They have incorporated reciprocating pedal drive to make trike reversible. It was done in consideration of force distribution, FOS (factor of safety) and Deflection of beam which thus gave rise to a fully triangulated frame with proper load distribution. Use of reciprocating pedals on front wheels led to increase in staring torque and decrease in human efforts and to make wheel reversible.

Er. Vikas Gulati et al. (2012) carried out finite elemental analysis of the chassis and calibrated stresses on individual elements of the chassis. Steering geometry was designed and analysed using peter elands spreadsheet to carry out geometrical analysis. Similarly suspension analysis was carried out on suspension analyser v5 and suspension geometry was fixed. MacPherson strut suspension was used after suspension analysis.

Palash Patodi et al. (2014) deduced the geometrical method for estimating the centre of gravity. The methodology used here is estimating the height of centre of gravity from the ground for tadpole trike using moment calculations considering appropriate wheel track. Roll over stability is compared for delta and tadpole trike Oversteer / Understeer Characteristics. The centre of gravity height may thus be one and a half times the wheel track. The single front wheel layout naturally oversteers and the single rear wheel layout naturally understeers. Having one wheel in front and two in the rear for power reduces the cost of the steering mechanism, but greatly decreases stability.

M. Reddi Sankar et al. (2013) fabricated solar assisted bicycle consisting of following components: hub motor, solar panel, voltage regulator, lead acid battery, motor controller, accelerator and bicycle. Solar cells are electrically connected and fabricated as a module with a sheet of glass on top to allow light to pass and protect the semiconductor from the weather. To obtain a desired peak DC voltage we will add solar cells in series, and to obtain a desired peak current, the solar cells are put in parallel position. This bicycle is cheaper, simpler in construction & can be widely used for short distance travelling especially by school children, college students, office goers, villagers, postmen. It can be driven by manual pedalling in case of any problem with the solar system. It has fewer components, can be easily mounted or dismounted, thus needs less maintenance.

Patrick Fenner (2010) calibrated method to determine position of centre of gravity Roll over stability was checked by calculating the maximum cornering velocity of a standardised model for each wheel arrangement with a selection of centre of gravity positions and for cornering with no change of speed, cornering with 0.25g braking and cornering with 0.25g acceleration. To ensure stability of a trike with two wheels on the front axle, the centre of gravity (centre of mass) must be a third of the wheelbase back from the front axle. Rollover stability is increased when the centre of gravity is closer to the two-wheel axle, and when braking though a corner for the tadpole, and accelerating with cornering for the delta.

Upendra S. Gupta et al. (2015) designed human efficycle which is a human powered velomobile with inbuilt Programmable Position Control Gear Shifter using Stepper Motor. Frame Configuration, Design & Material. This tri-cycle is powered by two humans simultaneously and also by a 373 Watt Geared PMDC (Permanent magnet dc motor). It is an eco-friendly human powered vehicle with a compounded electric drive system. An impact test was done using ANSYS12.0 software. Chassis could withstand the weight of the drivers and the components associated with the vehicle during static as well as dynamic conditions. A safety factor of 1.4 was obtained.

Literature survey on designing steering geometry:

Shawn Miller (2010) designed steering geometry to allow vehicle to navigate smooth, safe turns at any speed while minimizing turn radius and reducing scrubbing of tires in his paper. According to his research three important aspects which have to be taken into consideration while designing the steering geometry are centre point steering, caster angle, camber. Bump steer consideration is to be accounted for the velomobile design to ensure the safety of the rider. It was found that a linkage steering system incorporating an Ackerman design would provide

greatest benefit and control for steering needs. It was found that a slight "toe-in" to the front tires would result in better tracking for the vehicle. This will involve creating a slight four to five degree angle to both front wheels resulting in the front of both front tires being closer to each other than the back.

Literature survey on selection of Chassis material:

Forrest Dwyer et al.(2012) carried out FEA analysis for calibrating fatigue life of aluminium bike fames. After analysis on software the material or the frames were taken for physical testing. The finite element methodology proved to be an accurate way of predicting fatigue failure locations and cycles to failure. This was validated based on the methodology agreeing with the physical testing results. Aluminium 6061 was proved best for bicycle frames .Aluminium has a number of properties that make it more desirable when compared to other materials such as low density, ease of welding, good strength when heat-treated 13 and high corrosion properties

Ping Hwa LIM (2001) incorporated his research in fatigue Behaviour of 6061 Aluminium alloy and its composite. Standard metallographic techniques, as well as fractographic observation under a scanning electron microscope were used to further investigate material behaviour. Particularly large particles of SiC are identified as having contributed to fracture behaviour, along with poor interfacial properties. The 6061 Aluminium alloy exhibits higher ductility, better strength but lower Young's Modulus than its particle reinforced composite. The addition of the reinforcement SiC particles to 6061 did not improve strength over the conventional 6061 alloy.

Velveeta Lakshmikanth Chowdary et al. (2014) generated feature based model by using pro e, carried out thermal analysis of aluminium alloy and other components like carbon reinforced polymer etc. The Structural analysis and Thermal analysis results using aluminium alloy and Carbon Reinforced Polymer the stress values are within the permissible stress value. So using Aluminium Alloy and Carbon Reinforced Polymer is safe and robust for using in disk brakes

LITERATURE survey on suspension design and analysis:

A.V.Lade et al. (2004) carried out analysis of cad model of spring. In this paper the spring of mono suspension system from bike is being considered. After dissembling, the dimensions are taken from spring. The CAD model was made in pro\e and then analysed using FEA software named Ansys. The constraints are applied at the end of the spring, and force is applied at the centre to the other side of spring. Shear stress and deflection are evaluated for different materials. It has been observed that deflection for carbon steel is lower than deflection of other materials with same shear stress and the maximum value of deflection is found in brass with same shear stress. Mono suspension has advantage over dual suspensions links as dual suspension links may undergo uneven deflection.

Prof. D. K. Chavan et al. (2013) in their paper on Suspension in Bikes Considering Preload, Damping Parameters and Employment of Mono Suspension in Recent Bikes have explained the methodology of suspension-damper system. Shock absorbers work on the principle of fluid displacement on both the compression and expansion cycle. The modern motorcycle uses suspension to accomplish several things; it provides a smooth comfortable ride absorbing bumps and imperfections in the road.

Literature Survey on incorporation of hub motor:

David Faszer et al. (2006) used 1500 watt Brushless Scorpian motor 4020-16 which is incorporated along with pedalling and physical testing. In order to design and build the internal components of the gearbox, many steps were performed. The first step to select the gears that were to be used. After the gears were selected, the bearings were selected based off the equivalent forces. After bearings have been selected based off manufacturing specifications, the shaft were designed and then outsourced for manufacturing. Stage halves were created on CNC. Power assist was successfully incorporated.

D.J. van Schalkwyk (2006) carried out research on effect of Hub Motor Mass on Stability and Comfort of Electric Vehicles .Here the effect of the added mass of a hub motor on the response of a vehicle's suspension system is studied. Full finite elemental analysis is carried out for stresses on each components of the frame. Simulation results are verified with the use of practical experiments. The hub driven vehicle shows increased variation in natural frequency caused by payload variations. It is possible to improve the comfort of the vehicle by designing. The suspension system to match the mass distribution. The mass of the motor or battery can thus be adjusted for getting proper centre of gravity.

Literature survey on synchronization of two velomobiles(master-slave concept):

Jianping Cai et al. (2006) researched on Synchronization of a class of master-slave non-autonomous chaotic systems with parameter mismatch via sinusoidal feedback control. This involved Master-slave synchronization scheme of two n-dimensional non-autonomous chaotic systems coupled by sinusoidal state error feedback control, where parameter mismatch exists between the external harmonic excitation of master system and that of slave one. A concept of synchronization with error bound is introduced. The synchronization criteria are in the form of algebraic inequalities, so they are convenient in applications. The bounds of synchronization error were estimated analytically.

Literature survey on fabrication of velomobile:

S Sasiraaju A. S. et al. (2014) used GMAW Multi pass welding for the thick sections was carried out and analysed for the Chromalloy steel plates. The presence of hydrogen has been suppressed by selecting low hydrogen electrode. The shielding gas composition used in this analysis is 80% Ar-20% CO2. By testing the hardness of the base metal and welded v groove surface in the metal the hardness value of the base metal is around 64 HRA where the v groove surface has around 52 HRA so we can say the hardness value around the metal is averagely around 56 HRA. So we can use the metal with weld in the high tension and strain areas.

Dr.Joshi.C.Haran et al. (2013) carried out static analysis of airless tyres. In this analysis non-pneumatic tyres are replays by poly-composite material tyres in place of air. The construction and material study of these tyres is done by comparing it with pneumatic tyres. A brief structural study on spokes of airless tyres is done and is related with rolling resistance and fuel efficiency. For the airless tyre to perform with low rolling resistance following conditions are decided: (i) since polyurethane composite has the capacity of both elasticity and stiffness at the same time, it becomes ideal to perform better than pneumatic tyre in case of rolling resistance. (ii) From the structural analysis, it can be concluded that polyurethane offers a wide range of operation applicable for various load applications.

Literature survey on Project management:

Theodoros Kosmanis et al. (2011) carried out research on management of the project, working with prototypes of human powered vehicles. Outcomes of the project. The project management and the intensive work on international contacts support the international research involving innovation and new organizational structures.

Conclusion: From the above literature survey it is found that, Aluminium 6061 is best for chassis frames, Mono suspension has advantage over dual suspensions links as dual suspension links may undergo uneven deflection, Tadpole trike design has better efficiency than delta trike design. Also essential steering geometry considerations are studied for maximum stability and better handling performance.

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