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The Design of a Solar Powered Tricycle for Physically Disabled Persons_A Review Paper

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Abstract : A solar powered tricycle for the physically disabled persons has been designed using the simple surface structural (SSS) analytical method without the need for rigorous complex method of the finite element analysis (FEA) usually employed in automobile industry. The structural performance analysis and powertrain performance analysis were carried out in order to predict the vehicle performance at certain operational condition, and also to assist in powertrain selection and sizing. The Simple surface structural (SSS) analysis was performed on the tricycle frame to determine the deformation of the tricycle when it is subjected to the driver and goods payloads totaling 900N. The powertrain performance simulation was carried out on the tricycle using gross vehicle weight (GVW) of 1300N for only the driver, and GVW of 2000N when goods are on board under using different accelerations in starting from. This simulation output resulted in the selected BLDC motor of 5000W and a 3000W.h battery capacity. The structural performance analysis gave a maximum deflection of about 1.3mm which is within the safe limit. The tricycle will be able to cover a minimum distance of 10km and a maximum distance of 30 km depending on the payload and the road conditions.

***IndexTerms* - Solar Tricycle, Disable Persons, SSS, Battery Electric, Automobile**

INTRODUCTION

One of the important aspects of human survival is mobility. Mobility is essential to human beings in order to carryout daily activities, movement from one placed to the other. Occasionally, almost everyone faces one form of difficulties and hardship relating to mobility challenges. This challenge can be natural, due to health problems, or accident which are collectively known as mobility disability. But for persons with disability, barriers are more frequent and have a greater impact on their social and financial abilities. Many complications are associated with the mobility of the physically challenged persons in the society. The physically challenged persons for the purpose of mobility have been provided with assistive device such as crutches, prosthetic limbs, canes, walkers, manual wheel chairs or three wheelers for their daily activities. Despite the usefulness of the various assistive devices, one major disadvantage is the requirement of a rather excessive physical force by the users which in-turn causes undue stress to various body joints (shoulder, wrists, etc.).

In 2018 the reported unemployment rate was 23.1% with 87 million Nigerians living on less than $1.9 per day. Presently, the Nigerian economic have further depreciated due to the COVID-19 pandemic. The pandemic had led the country to a second recession in less than five years. From the above data we can have an idea about the financial state of the country and the likely effect on the physically challenged, many of them depends on alms for daily survival. The estimated number of disabled persons in Nigeria is about 25 million. Majority of the physically disable persons fall below the poverty line in the developing countries. The financial condition of those with disability is highly due to negligence of the society.

People with disability have a lot of challenges with lesser or no legal protection, and many are subjected to extreme poverty and poor health. High percentages of mobility related physically challenged persons have no access to education and when it is available is usually at low level educational achievement. In addition, they are hardly involved in cultural, social and political activities. These barriers experience by the disabled limits their financial potential thereby worsen their poverty level or indices.

In order to improve the standard of living of the handicapped persons, technological advancement in recent years have seen the simple manual assistive device for the disabled evolve into a more complex motorized device such as engine powered wheel chair and scooter with a higher efficiency and improved reliability. Regardless the improved efficiency and reliability of these engine powered vehicles using fossil fuel, they have impacted the local and global environment negatively, such as localized environmental emissions, depletion of natural resources, global warming, etc.

This negative environmental effect of the fossil fuelled engine powered device has prompted the need for a more innovative and environmentally friendly devices through the concept of design for environment (DFE). The DFE maybe describe as deliberate steps taken during design of product and product performance with respect to environmental well-being, safety, and sustainability over the full product and process lifecycle. According to a new market research report "Vehicles for Disabled Market by Vehicle Type (Adaptive Four-Wheeler, Mobility Scooter), Manufacturer Type (OEM and Third-Party Customization), Entry Mechanism, Entry Configuration, Driving Option, Ownership, and Region". The global vehicles for the disabled market is projected to grow from $ in 2019 to reach $6.3 billion by 2027, at a CAGR of 11.7%. It is in cognizance of the already discussed drawbacks associated with previously developed tricycles (and other assistive devices) for handicapped persons, and the current financial state of the physically disabled persons in the society. In addition to the projected market share as reported by marketsandmarkets, (2019).

NEED OF THE STUDY.

A S***olar Powered Tricycle for the Physically Disabled*** is being proposed. This tricycle would utilize the energy from the sun as the primary energy source for the power-train. This vehicle is being designed so that it can be used for local mobile marketing purpose. Hence, the vehicle provides the physically challenged the opportunity to become financially productive in the society. Since the solar vehicle utilizes renewable energy and does not burn fossil fuel it would have a zero-emission level and not produce greenhouse gases. In addition due to the simple nature of the vehicle jt will be nearly maintenance free.

The aim this project is to design a low-cost solar powered tricycle to assist in the mobility of physically disabled person and that can be used as a local mobile marketing device, and with the following objectives:

Carry out review of work already done in tricycle with conventional powertrain and solar battery electric powertrain, which is what this paper is set out to accomplish.

Design of the body and chassis of the tricycle using Computer Aided Design (CAD) software such as CATIA, SOLIDWORKS, PROE or AUTOCAD and carry out the structural analysis using the simple structural surface (SSS) methods commonly used in automotive body and chassis drawing and design. Select the solar battery electric powertrain components based on the design loads and size of the vehicle and do the cost analysis of the components for the construction. The solar powered tricycle is equipped with a passenger and storage compartment through the provision of a storage compartments, it provides an added benefit for the disabled persons for mobile marketing of consumables and other locally demand items. Rechargeable batteries will be installed to store extra energy from the solar panel. The tricycle is most suitable for persons with one foot or leg, and individuals with leg injuries or issues that require wheelchair or crutches for their mobility. This project will further enhance the student's knowledge and interest in vehicle drawing, design and analysis using solar battery electric powertrain technology, and its role in the advancement of future automobile industry. In addition, this work will benefit from the projected market value of the electric vehicle for the disabled locally as projected by marketsandmarkets. Lastly it will enhance our knowledge and skill to design for the environment of a tricycle for the physically disabled persons. This review is limited to the review of work done to date in this field.

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REVIEW WORK

The first historical records of a tricycle comes from second half of 17th century, a century and a half before the invention of first two wheeled bicycle that had no propulsion, and about two centuries before first mass produced chain-driven bicycle was reported by Herlihy (2006). This early example of tricycle was made by the aging German watch-maker Stephan Farffler who was disabled and could not walk. Farffler devised small carriage for one person that had three wheels with one in front and two at the back using simple mechanism in the front wheel that enabled him to rotate the crank with his hands and transfer power to the wheel.

In 1789 two Frenchmen named Blanchard and Maguire invented a tricycle, which was published by the Journal de Paris on 27th of July and it was named bicycle and tricycle so as to differentiate between the two types of machines.

By the 1884, over 120 different models of tricycle were produced by 20 English manufacturers who tried to satisfy the market for the simple to use personal travel devices. While the male population preferred the bicycles models such as penny-farthings (a direct-drive bicycle, meaning the cranks and pedals are fixed directly to the hub) and safety bicycles, female population that wore long dresses preferred tricycles and carriages that were propelled both by hand or feet pedals. The original tricycles were so popular in United Kingdom, that the country was one of the first to form official Tricycle Association, organize tours, day rides and yearly races.

Early Developments

In the early developments the tricycles were naturally adopted as means of mobility by the physically disabled. Although earlier developed tricycles were purely mechanical, still it is used in assisting the disabled in mobility. Currently, manually operated tricycles are the most commonly used disabled vehicles by the handicapped people for mobility in the developing world. It is generally operated by the use of hand or foot pedal and chain drive linked to the sprocket of the wheel rims. The wheels are rigidly fixed by the use of clamps, couplings and linked with the help of frames. The entire design of the tricycle is compact and has a simple mode of construction.

Among the few early developments in tricycles to be used by handicapped individuals is the outstanding "Front Wheel Drive Cycle" U.S. Patent. No. 3,848,891, issued in Nov. 19, 1974. Vittori patents a rider powered tricycle, having an arm powered front wheel drive mechanism, particularly adapted to be used by paraplegic individuals. Prior to the invention of the Vittori's Tricycle, the physically disabled had always struggled with tricycles as the hand crank mechanism employed is in close proximity with vertical turning axis of the front wheel.

A major advantage of the Vittori's tricycle was that, it was easily adopted by the physically disabled persons (particularly, the paraplegic individuals) as it provides greater comfort while riding than previously developed tricycle by other inventors. The Vittori tricycle has unique steering system design, which aided steering when negotiating bends or cornering through the provision of a tiller assembly. In addition, the tricycle was design to have its center of gravity acting close to its rear wheels, thereby enhancing the steering and stability.

Though, the Vittori's tricycle was a notable invention, it was criticized on the basis that the design only allows for the use of hand powered and front wheel drive mechanism to propel the tricycle. The tricycle was also criticized for lack of adjustment to accommodate different paraplegics, or the growth of the user. A major disadvantage was that, there was no way to accommodate the feet and legs of certain types of handicapped children who may have limited use of their legs, or in cases where there is need to exercise the legs to aid recovery process. Therapeutically, this may be important as handicapped person may be required to regularly exercise their legs for the benefits of recovery.

In response to the challenges faced by the Vittori's tricycle, an inventor, named Richard Vanore patented the "Tricycle for Handicapped Individuals"; U.S. Pat. No.4, 152,005, issued on the 1st of May,1979. This tricycle had a hand crank coupled through a chain drive linkage to the front wheel, and foot pedals coupled by means of a chain drive linkage to the rear wheels. A frame was used to support the front wheel and the chain drive linkage, the rear wheels and their chain drive linkage, and the seat assembly. Adjustments were provided for positioning of the seat with respect to the tricycle frame, the position of the hand crank with respect to the frame and the seat. Adjustments were also used for positioning of the foot pedals with respect to the frame and the seat.

Various modifications were done on tricycle for the mobility physically challenged during the early days of tricycle development in the 18th and 19th century. The modification of the tricycle was always limited to manual operation in particular the crank propulsion mechanism. Low mechanical efficiency is a key setback of the manual propulsion mechanism. The reduced efficiency is highly noticeable when propelling through off-road terrains like hills and muddy environment.

Recent studies on the effect of hand pedaling on the body joint showed the possibility of repetitive strain injury on the upper limb, especially when cycling at higher gear ratio was reported by Faupin et al., (2006).

Recent Developments

The development of tricycles for the disabled has undergone a rapid development due to the use of battery electric powertrain and solar energy. In the pursuit for greener vehicles, policies developed and enforced by the European Union (EU) have since led to better vehicle designs and alternative means for power production in vehicle. By using renewable energy as an alternate means for power production in vehicle, issues such environmental pollution due to discharge of harmful exhaust gases from the internal combustion engine vehicle would be effectively mitigated. The transition from mechanical to battery electric tricycle saw development of hybrid tricycle. A number of engineers and researchers investigated different power modes of the hybrid tricycle.

Ying and Sundarrao (2014), in their project on power assist hand tricycle with battery for disabled persons. In their work, design modifications was made to a pre-existing hand-crank tricycle that was originally designed to be used by disabled person with lower extremity weakness but with power in his or her hands and arms. The tricycle was modified by the addition of an electric motor and battery to be used as an alternate power source for propulsion. The motor controller can adjust the speed in five different settings and the tricycle can be driven forward or backward. The wheels were arranged with one fixed direction drive wheel in front and two pivoting wheels for steering in the rear. Two handles beside the seat are used for hand control of the steering. A large sprocket 25.4 cm in diameter located in front of the driver is connected with two crank handles for the driver's hands to power the vehicle. The tricycle was propelled mechanically by the used of the hand crank propulsion mechanism and the maximum speed attained by the modified tricycle was about 2.6km/hr.

Daniel et al. (2004) in their work on Electric Tricycle: Appropriate Mobility were successful in adding battery electric power train and control system to a pre-existing hand-powered tricycle to provide the users with improved levels of mobility. Their design objective was a simple and affordable design for the power train and controls, a design that needed to be reliable, sustainable, and functional. The design was adaptable to almost any pre-existing hand-powered tricycles with little modification required. The components of the design includes; electric motor, a drive system, steering controls, and a power supply unit.. Their aim was fulfilling a number of objectives such as a top speed to 3.13m/s, a power supply that will provide a range of 12.87km??? at maximum speed, total cost of power train and controls and power supply will not surpass 122,964 naira. The tricycle had the advantage of successfully eradicating the need for human power for propulsion, thereby enabling maximum comfort during driving. However, in their design the battery must be detached from the tricycle and find an electrical power supply when there is need for recharge.

Baba Hassan (2012) in his project on the design and fabrication of a motorized tricycle for disabled persons, which was designed for users of healthy upper torso with pelvic to foot restraint. The structure was designed to aid the transition from a wheelchair to the tricycle. That is, the disabled person would be able to access the tricycle without having to go through the trouble of disembarking from his or her wheelchair. To achieve his objectives, a special platform that allows the wheel chair to be wheeled up or down was designed into the tricycle frame design. At the design stage anthropometric data were considered in the design of the platform and frame of the tricycle. His designed tricycle has a payload of 95kg, maximum speed of 45km/hr, fuel tank capacity of 4 liters, fuel consumption rate of 1.2 liters and a battery capacity of 12V 4AH.

Use of CAD in vehicle design

The evolution of computer aided design (CAD) systems and related technologies has promoted the development of software for the design of vehicle chassis modeling. It visualizes the main outputs of the model, which consist in numeric data and graphic elements. This reduces the simulation time and enables the optimization process in engineering and vehicle design..

The computer-aided three-dimensional interactive application (CATIA) software is a complete multi-platform solution for computer-aided design (also provides 3D design), manufacturing, engineering, and product life management (PLM). The PLM was developed in 1970s and marketed by manufacturer Dassault Systèmes. According to Aysha M, (2020), CATIA software is ideal for creating solids, surfaces, assemblies, drawings, fabrication and analysis.

Taufik et al. (2014) developed an electric car chassis design by using the CATIA V5 R19, his design was for adequate stiffness and strength. The material utilized in this project was mild steel AISI 1018 with 386MPa of yield strength and 634MPa of ultimate strength. His design in CATIA platform was then imported to finite element analysis (FEA) software, where the car chassis was simulated with nine different static loads of 700 N to 1500 N. A safety factor of 1.5 was taken into account during the analysis. Their result showed that the critical point of stress and displacement occurred in the middle of the side members of the car chassis in all the loading conditions, and the maximum stresses are below the yield stress.

Abdulazeez (2018) in his dissertation titled vehicle occupant accommodation based on Nigerian anthropometric data. His work was aimed at designing vehicle seats for the Nigerian population based on their anthropometric data and analyzing postural problems by means of digital human modeling systems. A controlled selection of subjects reflecting the ethnic, age, gender and anthropometric spread of the Nigerian population similar to that undertaken by automotive companies was conducted. A total of 863 persons comprising 460 males and 403 females participated in the exercise and 60 body dimensions applicable in automotive seat design, digital human modeling and vehicle occupant packaging were obtained using standard anthropometric instruments. The data obtained were statistically analyzed using statistical package for social sciences (SPSS) to obtain the necessary percentile values as well as the means and standard deviations. The results obtained were used to propose some recommendations for automotive seat fit and occupant packaging dimensions for use in the design of vehicles intended for the Nigerian market. This is to ensure an optimum fit between the vehicle interior package and the occupants, as well as providing adequate accommodation. An ergonomic automotive seat suitable for the Nigerian population was designed using CATIA V5 software based on the proposed established dimensions. Six custom built Nigerian manikins were postured as drivers and passengers in a vehicle package based on CATIA V5 human builder vehicle occupant accommodation and another seven manikins were positioned on the seat designed for the Nigerian population. In conclusion, rapid upper limb Assessment (RULA) ergonomic analysis conducted on all the manikins in the vehicle package both the driver and passengers showed that the seat designed for the Nigerian population proved to fit and accommodate them comfortably with acceptable RULA scores of 2 for all the seven Nigerian manikins analyzed.

Vehicle Body Design using the SSS Methods

Simple Structural Surfaces (SSS) method was originally developed to analyze the load path of the vehicle during the concept stage of the design process. It helps to design automotive vehicles with a simple structure during the conceptual stage of design (Brown and Robertson, 2002)to enable early decisions and key areas that may require indept study before using the advanced FEA. The application of this simplified approach is highly beneficial in the development of modern passenger car structure design. Furthermore, it is useful to enhance the understanding related design concepts and structural body of the vehicle.

Nor et al. (2017) in their work on the Development of Vehicle Model Test-Bending of a Simple Structural Surfaces Models for Automotive Vehicle Sedan, developed a physical SSS of sedan model. Structural analysis, such as bending test was performed on the developed SSS sedan model. The test allows for relative comparison of bending stiffness when one or more panels are removed from the complete SSS structure. Their analysis was done on the complete model by applying load at the middle floor using 200g, 400g, 600g, 800g, 1000g and 1200g. The results from their analysis shows the bending stiffness for complete model, without a windshield frame and the windshield, and front parcel shelf is 353.8N/mm, 218.6N/mm and 33.37N/mm respectively. They observed that the bending stiffness reduced by approximately 38% compared to the complete body stiffness when windshield is removed from the complete body of SSS model. The bending stiffness decreases considerably (more than 90%) when both windshield and front parcel shelf are removed from the SSS model. In their conclusion, the results prove that the proposed vehicle model test is useful to physically demonstrate the importance of providing continuous load path using the necessary structural components within the vehicle structures. In addition, the analysis shows that the front panel shelf is an important subassembly to sustain bending load.

Integration of Solar Battery Electric Powertrain into Tricycle

According to Fathabadi, (2018), electric vehicles is an adequate substitute to the internal combustion engine vehicles. The major components of the powertrain for the electric vehicle are electric motors and batteries, where the batteries served as the storage elements. It is estimated that by 2050, around 100 million of EVs will be sold per year worldwide (Rodrigo, 2013). However, the EVs are still not popular because of two important challenges, driving range and cost. The driving range or range of the EVs is defined as the maximum possible distance traveled by the vehicle per charge. It depends upon the power of the electric motor, the capacity of the battery, and the overall powertrain efficiency. Increasing the capacity of the battery will lead to the increase in the cost of the vehicle and as such high number of research work is on increasing the overall efficiency of the system.

The efficiency of an electric vehicle can also be improved by integrating photo-voltaic (PV) panels to the electric vehicle powertrain. By introducing solar panels to the EV's, we are combing energy source from the electric batteries and the solar panel. The resulting powertrain from this modification is called a solar battery electric powertrain (SBEP), and the vehicle which it is installed is called solar electric vehicle (SEV). SEV is made of PV panels, battery, electric motor, vehicle controller and vehicle body. In good sunny conditions, SEV doesn't need an industrial power charging for the designed duties. The SEV can achieve low-carbon, energy saving, environmental protection and zero-emissions for the future of human life.

Su et al., (2010), in their research on green solar electric vehicle changing the future lifestyle of human. This project paper claimed Solar Electric Vehicle (SEV) is the future of the automotive industry. These claims were made based on the advantages offered by the SEV. The advantages include no noise, pollution free,

energy saving and reduced greenhouse gas emission. To further support their claim, they carried out a research on the performance of a Solar Electric vehicle (SEV) called Kundi, that can be purely solar or battery powered,. When put to road test, the vehicle travelled an average distance of 135km on one charge on good sunny days.
Masud et al., (2017) carried out the design, Construction and Performance Study of a Solar assisted tricycle using dual mode of charging. The tricycle works on a 24V 28Ah battery, the vehicle covered a distance of 25km in 180mins before the battery becomes fully discharge. The solar panel provided 24% of the power required to run the vehicle for 180mins drive time, the weight of their designed vehicle was 150 kg for a maximum speed of 26 km/h.
In the reviewed literatures, electrical and solar tricycles have contributed enormously to the mobility of the physically disabled persons, but the solar tricycle shows a greater promise as it is able to extend the range of a conventional pure or hybrid battery electric vehicle. In addition, this will provide an opportunity for the students to know how to design and develop a vehicle by starting from a lower-level design of the tricycle that does not involve the complexity of using the finite element methods for load analysis. In addition, the vehicle is designed to enable the user to put it into commercial use in the form of mobile marketing.

Conclusions and Recommendations

This work presents a mobility solution for the physically disabled persons. The aim of this work was to design a low-cost solar powered tricycle for the physically disabled. The tricycle was designed to include spaces for passengers or goods compartment. The design analysis includes structural performance analysis and powertrain performance analysis to properly predict the vehicle performance at certain driving condition, and also to assist in powertrain selection and sizing. Results from the structural performance analysis suggest a maximum deflection of about 1.3mm when the vehicle is under the total weight of 900N (combined weight of the driver and goods). The powertrain including the motor, battery, and solar panels performance analysis shows that the tricycle will be able to cover a distance of 10km and a maximum distance of 30km depending on the tricycle payload and the road condition. A thorough review work done by others has been reviewed towards the main project. In recommendations, several improvements and modifications can be made on the vehicle in order to increase its performance characteristic for various driving conditions. To accomplish this, the followings are recommended, selection of a battery with a higher storage capacity and an electric motor with a higher power rating. This will go a long way at increasing the driving range before the need for recharge and also allow the vehicle to cruise at higher speed. The introduction of a voice control intelligence system to the disabled vehicle, as this would let the vehicle offer a more efficient service to the user. The introduction of a differential system to the rear axle of the tricycle, this is to enable the tricycle manoeuvre sharp corners or bends easily without skidding or slipping in the process. These will be taken into considerations during the design stage which is the next phase.

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