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DESIGN AND CONSTRUCTION OF SELF-CHARGE ELECTRIC VEHICLE

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ABSTRACT

This research seeks to design and convert an IC engine vehicle into a self-charge electric vehicle. The design characteristics of the components of the electric vehicle including the chassis, the mechanical components, and the electrical systems was analytically determined, the rolling resistance and grade (gradient) resistance of the electric vehicle was evaluated, and the aerodynamic drag force and acceleration force of the electric vehicle was determined. The life cycle of the battery in the electric vehicle was determined. Ultimately, the designed electric vehicle was modeled, fabricated, and simulated for its performance improvement to analyzing the stress, strain, and total deformation of the chassis (mechanical structure) of the electric vehicle. Analytical machine design methods were employed to analyze the design data of the electric vehicle while Solidwork computer-aided design (CAD) and ANSYS finite element modeling (FEM) tools were employed to model and simulate the vehicle's operational performance. The design results from the analysis showed that the designed electric vehicle weights 13510N, rolling resistance of 198.79N, grade resistance of 0N, aerodynamic drag force resistance of 125.129N, total tractive effort of 323.982N, the torque required on the drive wheel of 47.625N and a battery life cycle of 650cycles. Performance analysis showed that the total deformation on the chassis of the electric vehicle with maximum stress 115.88MPa and equivalent elastic strain 0.009mm is 5.4782mm. The simulation was done using the parallel configuration in Simulink modeling (MATLAB software) to obtain vehicle performance results and the result from the simulation revealed that the speed and torque parameters obtained also meet the necessary characteristics that are required for driving electric vehicles. The relationship between tractive force and % loss of torque of the electric vehicle was analyzed. The result shows that the tractive force of the electric vehicle is inversely proportional to the % loss of torque of the electric vehicle. The analysis revealed that there exists a very strong correlation (correlation coefficient (R = 0.889) between tractive force and % loss of torque of the electric vehicle. The relationship between the weight of the electric vehicle against the tractive force of the electric vehicle was analyzed. The analysis shows that the tractive force of the electric vehicle is directly proportional to the weight of the electric vehicle. The analysis revealed that there exists a very strong correlation (correlation coefficient (R = 1) between the weight of the electric vehicle against the tractive force of the electric vehicle. The relationship between the weight of the electric vehicle against the % loss of torque of the electric vehicle was analyzed. The analysis shows that the weight of the electric vehicle is inversely proportional to the % loss of torque of the electric vehicle. The analysis revealed that there exists a very strong correlation (correlation coefficient, R = 0.888) between the weight of the electric vehicle and the % loss of torque of the electric vehicle. The relationship between the grade resistance of electric vehicles and the slope angle of the road was analyzed. The analysis shows that the grade resistance of electric vehicles is directly proportional to the slope angle of the road. The analysis revealed that there exists a very weak correlation (correlation coefficient (R = 0.018) between the grade resistance of electric vehicle and the slope angle of the road. Conclusion and recommendations were made that instead of using Lead acid battery which needs replacement after some period, Lithium-ion batteries can be used which provides more life cycles and are much more reliable for effective operation.

1. INTRODUCTION

1.1 Background to the Study

This research analyzed the design and fabrication of an electric vehicle. The design parameters and specifications of the components of the electric vehicle including the chassis, the mechanical components, and the electrical systems were analyzed. The rolling resistance, grade (gradient) resistance, aerodynamic drags, and acceleration force of the vehicle were assessed. The total tractive force of the vehicle was analyzed as well as the torque required in the drive wheel was determined. The life cycle of the battery was also determined. The design process of the mechanical structure was carried out using Solid Works software and the model was developed. Several models were developed before actually confirming the final design. Due to several reasons such as material wastage, cost-effectiveness, time involved in fabrication, and difficulties in manufacturing, several design changes were made and obtained as the final model. The simulation was done using the parallel configuration in Simulink modeling (MATLAB software) to obtain vehicle performance results, as well as to determine if the tractive force and torque parameters obtained also meet the necessary characteristics that are required for driving electric vehicles.

EVs can be electric two-wheelers (E2Ws) like electric bi-cycles and electric scooters, three-wheelers like E- rickshaws and four wheelers consisting of electric cars. Usually, a vehicle consists of four wheels and it will be powered by an internal engine. Automobiles are used to transport from one location to another. Automobiles generally use gasoline to fuel the internal engine, but technological advances have led to the design of cars that run on electricity and even water. EVs are a relatively straightforward modification of traditional internal combustion vehicles, but they have new consequences for the infrastructure of transportation and energy. Globally, the urgency to look at sustainable mobility solutions to reduce dependency on imported energy sources, reduced greenhouse gas emissions, and mitigates adverse impacts of transportation including global warming has been recognized (Manikandan, & Logesh, 2018). The carbon dioxide emission can be reduced by taking precautionary measures to reduce the catastrophic climate change that threatens the species of this planet. Major endeavors have been taken for minimal use of fossil fuels for power generation, transport propulsion, reduction of energy consumption, and protection of carbon sequestration. EVs could be the alternative to decrease CO_2 gas emissions. Electric vehicles offer advantages and disadvantages, despite their rapid development. The key benefits are that it uses less gas, produces fewer emissions, and is more economical. Longer recharge times, battery replacement, and fewer charging stations are its drawbacks. In this study, an effort was made to design and create a self-charging EV in response to these issues. The power source for electric motor-driven cars is typically a battery, and how well the battery can be charged determines how well the vehicle will operate. Moreover, the battery may only be charged when the vehicle is stationary. To break through, this research designed and modeled an electric vehicle that generates power by itself while the vehicle is in running condition and the battery is getting charged simultaneously. This was done by coupling a dynamo with a motor which generated current when the vehicle is in running condition and stored the generated current in the battery.

2. LITERATURE REVIEW

2.1 Extent of Recent Work

One of the main difficulties facing modern civilization is the rapid depletion of fossil fuels as well as the environmental effects of their by-products, according to NavanithaKrishnan et al. (2020) in the design and fabrication of smart hybrid vehicles. Worldwide, all types of transportation use a significant amount of fossil fuel. The result was the emergence of hybrid EVs (HEVs), which promoted "fuel economy" and "clean environment" as their key marketing slogans. Their project dealt with the design and fabrication of a smart hybrid vehicle that simply beads a petrol engine and a dynamo with which the battery is charged. They stated that hybrid vehicles are the best concept for future transportation. People can choose between charging and using gasoline or any other fuel, but in India, where there is already a shortage of energy for home use, setting up an e-station is a new challenge. Moreover, 80% of Indians cannot afford the price of a hybrid vehicle. Their engineered vehicle has exceptional fuel efficiency and self-power penetration. Fuel was used to power the alternator. An automobile is fully functional with a gasoline engine and battery. They claimed that one of the most promising solutions to lower fuel consumption and environmental pollution is the use of hybrid automobiles. They continued by saying that smaller engines, lighter parts, and fewer moving parts all contribute to hybrid vehicles' improved efficiency. Moreover, energy is captured and reused in a hybrid vehicle, whereas, energy is lost through the heat in a conventional fuel vehicle in most cases.

The simulation of an EV with various power train components was carried out by Vyas (2017). His research's objective was to use a simulation program, in this case, MATLAB Simulink, to build an energy model of an EV that included several power train components. According to him, this model calls for the vehicle to have energy consumption as a result of various pressures occurring on it during various regular driving cycles. This report also includes a market analysis of several cars now available that run exclusively or partially on electricity.

Samuel (2015) researched the development and production of green automobiles. Their study demonstrates the future generation of solar- and wind-powered power generation technologies. The wind's kinetic energy and solar energy were used to create the electricity. Both methods were used to generate electricity while the car moved. One is created by a turbine, and the other by solar energy. It is kept in the battery to keep the car operating. The operation made use of a DC motor. His research revealed the best locations and configurations for these components to be fitted to generate the most electricity. The vehicle's weight was decreased since the gearbox and the engine was removed.

Sasikumar *et al*. (2018) carried out the design and fabrication of a solar car. The primary goal of their venture was to structure and create the Electric Solar Vehicle which is intended for single-seated vehicles fuelled by a 2 kW BLDC center engine (motor). Electric sun-oriented vehicle was fabricated to improve safe and Eco-friendly transportation.

They stated that in the current scenario, due to the increase in population and usage of vehicles, the consumption of fossil fuels like petrol and diesel keeps increasing. As a result of the premise above, there will be less fossil fuel available, which could raise demand and prices until they are exhausted in the future. As a result, alternative fuel sources must be discovered to power the vehicles. Additionally, they noted that solar energy is one of the freely accessible non-renewable energy sources.

It is believed that daylight is a source of energy that can be used in a variety of ways. The energy from the sun is used to generate power during the day. A solar panel that is powered by the sun and a battery that stores electrical energy are the basic components needed to build a vehicle that runs on sunlight. The sun-based cells gather a bit of the sun's vitality and store it in the batteries of the solar-based vehicle. After the vitality is stored in the batteries, it is accessible for use and the engine and controller are made to drive the vehicle.

3. MATERIALS AND METHODS

The research approach that served as the foundation for this study is data gathering, analysis, design, and conversion of ICE to a self-charging EV is presented in this chapter. It offers a good methodology for reaching the goals and objectives of the research.

3.1 Research Approach

To develop and convert an ICE into a self-charge EV in Nigeria. The home base self-charging EV design information and data is obtained from secondary sources through literature research as well as primary sources through interviews with firm personnel in local vehicle assembly and repair workshops in Rivers State and other regions of Nigeria.

The materials that were chosen in this study for the design and construction of a self-charge EV are data on the mechanical, electrical, and physical properties of the components and systems in the electric vehicle including the chassis, the mechanical components, the electrical system, and the body. Data on the type of materials used in the specification and geometry of the electric vehicle’s components and systems also constituted part of the materials used in the study.Additionally, other materials used in the research were data for the isometric orthogonal projection required to design the machine as well as the computer aided design (CAD) and simulation software required to respectively model and simulate the EV design and operational performance.

4. EV DESIGN CHARACTERISTICS

Some design inputs were required for computing the design results of the EV. These input parameters and their corresponding values are shown in Table 4.1, 4.2 and 4.3.

Table 4.1- EV Design Input Parameters

Type	Dimensions
Wheel Base (mm)	2005
Overall Width (mm)	1460
Overall Length (mm)	3180
Overall Height (mm)	1815
Front Track (mm)	1060
Rear Track (mm)	1260
Minimum Ground Clearance (mm)	180
Cargo Box Dimensions (mm)	1570 X 1460 X 380
Vehicle structure	Mild steel
Wheel (inches)	10

Table 4.2 Specifications of the Electric Vehicle’s Components

S. No.	Components/Parts	Details
1	BLDC Motor	3kW – 60V – 3 Phase Brushless Dc Motor
2	Clutch	Type: Multi – Plate Wet Clutch
3	Gearbox	4 – Speed Sequential Gearbox
4	Suspension	Front: Independent suspension with MacPherson Strut Rear:

		Spring with telescopic shock absorber
5	Brakes	Front: Hydraulic Rear: Drum
6	Battery Pack	Lead-Acid 12V, 75Ah
7	Controller	60V

Table 4.3 Specifications of the Electric Vehicle's Alternator

Type	**A**
Rated Voltage	12V
Nominal Voltage	40A @ 13.5V
No load speed	1100rpm
Setting Voltage	14.2 – 14.8
Polarity	Negative ground
Rotation	Clockwise

4.1.2 Electric Vehicle Design Calculations

The design input parameters were substituted into the design equations and results for component parts of the electric vehicle were obtained. The calculations are shown below.

4.1.2.3 Determination of Electric Vehicle Weight.

Given a motor speed of 3000rpm and power of 3KW and maximum velocity of 30km/hr (8.333m/s), the shaft torque T of the DC motor is determined firstly as:

$$Power = \frac{2\pi NT}{60}$$

But from the above, making T subject of the formular, we have:

$$T = \frac{60P}{2\pi N}$$

Substituting values into the equation above, we have:

$$T = \frac{60 \quad x \quad 3000 \quad x \quad 0.75}{2 \quad x \quad 3.142 \quad x \quad 3000}$$

$$T = \frac{135{,}000}{18{,}852}$$

$$T = \frac{135{,}000}{18{,}852}$$

$$T = 7.1610\ Nm$$

The torque of the DC motor is determined as 7.1610Nm.

The velocity of the motor shaft is determined using:

$$V = R\omega$$

Making the axle speed subject of the formula, we have:

$$\omega = \frac{V}{R}$$

Substituting values into the equation above, we have:

$$\omega = \frac{8.333}{0.15}$$

$$\omega = 55.6m^2 / s$$

But, axle speed is also given by:

$$\omega = \frac{2\pi N}{60}$$

Making the motor speed N subject of the formula, we have:

$$N = \frac{60\omega}{2\pi}$$

Substituting values into the equation above, we have:

$$N = \frac{60 \quad x \quad 55.6}{2\pi}$$

$$N = 530rpm$$

Available Torque on shaft is determined as:

$$T = \frac{60 \quad x \quad 3000 \quad x \quad 0.75}{2\pi \quad x \quad 530}$$

$$T = \frac{135000}{3,330.52}$$

$$T = 40.53Nm$$

With 30% loss of torque, T is determined:

$$T = 40.53 \quad x \quad 0.7$$

$$T = 28.37Nm$$

The force on the vehicle is determined as:

$$F = \frac{T}{R_S}$$

Substituting values into the equation above, we have:

$$F = \frac{28.37}{0.15}$$

$$F = 189N$$

The weight on the vehicle is then determined as:

$$W = \frac{F}{\mu}$$

The rolling friction between vehicle tire and road is 0.02. Substituting values into the equation above, we have:

$$W = \frac{189}{0.02}$$

$$W = 9456.66N = 945.66kg$$

Without loss of torque, force is,

$$F = \frac{40.53}{0.15}$$

$$F = 270.2N$$

The weight on the vehicle is then determined as:

$$W = \frac{270}{0.02}$$

$$W = 13510N = 1351kg$$

Similarly, the calculation is made for 25%, 20% and 10% loss of torque and results tabulated in the Table 4.4.

Table 4.4 : Chassis Weight Comparison Table with %loss of Torque

Loss of torque	Force (N)	Weight (kg)
30%	189.13	945.7
25%	216.16	1080.8
20%	229.66	1148.4
10%	243.18	1215.9

5. RESULTS AND DISCUSSION

5.1 Results

The design results from the analysis showed that the designed electric vehicle weights 13510N, rolling resistance of 198.79N, grade resistance of 0N, aerodynamic drag force resistance of 125.129N, total tractive effort of 323.982N, the torque required on the drive wheel of 47.625N and a battery life cycle of 650cycles. Performance analysis showed that the total deformation on the chassis of the electric vehicle with maximum stress 115.88MPa and equivalent elastic strain 0.009mm is 5.4782mm.

The design analysis of the EV was done using the design input data comprising of the data of the type of material with data of the mechanical, electrical and physical properties of the components and systems in the EV including the chassis, the mechanical components, the electrical system, and the body as well as its geometric data required to design the vehicle. The 3-D model of the EV was generated using the data of its design characteristics through Solid Works Computer Aided Design (CAD)

6. CONCLUSION

This research work aimed to design and convert an IC engine into a self-chaege EV. The objectives of this research which were: to analyze the design characteristics of the components of the electric vehicle including the chassis, the mechanical components, and the electrical systems was achieved as presented in section 4.1.1 of the work, to determine the rolling resistance and grade (gradient) resistance of the electric vehicle, was achieved as presented in section 4.1.2 of this work, to determine the aerodynamic drag force and acceleration force of the electric vehicle was achieved as presented in section 4.1.2, to analyze total tractive force and the torque required in the drive wheel of the electric vehicle was achieved as presented in section 4.1.2, to determine the life cycle of the battery in the electric vehicle was achieved as presented in section 4.1.2, to model and fabricate the design characteristics of the components of the electric vehicle including the chassis, the mechanical components, and the electrical systems was achieved as presented in sections 4.1.3 and 4.1.4, to simulate the design characteristics of the components of the electric vehicle including the chassis, the mechanical components, and the electrical systems was achieved as presented in section 4.1.6, and to analyze the stress, strain and total deformation of the chassis (mechanical structure) of the electric vehicle was achieved as presented in section 4.1.5.

The results from the analysis has shown that the designed electric vehicle has a weight of 13510N, rolling resistance of 198.79N, grade resistance 0N, aerodynamic drag force resistance of 125.129N, total tractive effort of 323.982N, torque required on the drive wheel of 47.625N and a battery life cycle of 650cycles.

7. RECOMMENDATION

Based on the results and findings of this research, the following recommendations are made:

a) This vehicle uses a Lead acid battery which needs replacement after some period. Instead of using Lead acid battery, Lithium-ion batteries can be used which provides more life cycles and they are much reliable.

b) High rated DC motor can be used to drive the high loads as possible. New inventions of lighter but stronger materials like carbon fibers, and high strength polymers can help in reducing the overall weight of the vehicle and thus smaller sized high efficiency motors can be used.

c) Solar panels can be added to this vehicle to make it more economical.

d) The Government of the Federal Republic of Nigeria, and other relevant stakeholder within the country should assist in facilitating further research of this peculiarity by funding Nigerian Universities and research scholars as finance was seen as a major limitation of this study.

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