International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 13, Issue 6 [June. 2024] PP: 75-80

Design of Self- Charge Electric Vehicle

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Abstract

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.

Date of Submission: 03-06-2024 Date of acceptance: 14-06-2024

I. INTRODUCTION

1.1 Background to the Study

Electric vehicles (EVs) represent the technological bridge that points towards care for the environment, for sustainable and efficient vehicles for cleaner transportation (Koyanagi & Uriu, 2007). The constant increase in environmental pollution, and growing fuel prices contribute to the continuous search for solutions for cleaner transportation. The goal to reduce energy consumption, improve energy efficiency, and protect the environment stimulated people to think of owning EVs. In terms of cheap energy costs, great energy efficiency, and minimal emissions, EVs are viewed as a potential replacement for traditional transportation (El- Sharkawy, *et al.,* 2020).

The chassis, the mechanical components, the electrical system, and the body are the first four major design stages in the creation of an EV (Iqbal, 2005). All of these parts and systems in the EV are built to work together and rely on the integration of other parts. The quest behind the EV is to replace an internal combustion engine with an electric motor which is powered by the energy stored in the batteries through a power electronic traction inverter. The electric motor uses 90–95% of input energy to power the vehicle, which makes it a very efficient one (Albatayneh *et al.,* 2020). The key components of an EV are the chassis (mechanical structure), electric motor, battery, charging port, charger, direct current/direct current (DC/DC) converter, power electronics controller, regenerative braking, and drive system. The purpose of the electric motor is that utilizes the electrical energy stored in batteries for powering the EV. The EVs become environment friendly as they are recharged with lower emission power sources. The cells are charged by the electric grid. The primary function of the battery is to provide power to the electric vehicle to making it in running condition. Generally, EVs use lithium-ion batteries because they are more efficient than other cells due to their lightweight and negligible maintenance. The manufacturing of these Li-ion batteries is a bit expensive as compared to the nickel-metal hydride and lead-acid batteries. Depending upon the climatic location and maintenance schedule, the Li-ion batteries last up to 8 to 12 years (Kang & Recker, 2009). The charging port is the point that permits the vehicle to connect with an external power supply system through a charger to charge the battery. The function of the charger is to take the alternating current (AC) supply from the power source using a charge port and converts it into DC power for charging the battery. It also monitors the voltage, current, temperature, and state-of-charge of the battery while charging it. The

DC/DC converter converts high-voltage DC from the battery to low-voltage DC power to run the vehicle accessories. The power electronics controller controls the speed of the traction motor and torque by managing the flow of electrical energy from the traction battery. Regenerative braking is crucial for preserving vehicle strength and generating more energy. The mechanical energy from the motor is used in this braking technique, which then transforms kinetic energy into electrical energy to replenish the battery. Regenerative braking is frequently used in all EV models since it increases the EV's range (Daina et al., 2017).

Quinn (2016) studied the design, implementation, evaluation, and results of a race car for the collegiate formula Society of Autombile Engineers (SAE) Electric Competition. He asseverated that the Formula SAE Electric competition is a collegiate autocross event in which teams design, build, and race an open-wheeled electric race car. The main motivation is the efficiency advantage of electric motors over internal combustion motors. His study presented the design and evaluation of two generations of Portland State University electric race cars. The constraints are the competition rules, finances, human resources, and the time required to complete a race car in one year. The design includes the implementation of existing components: battery cells, controllers, electric motors, drivetrains, and tire data for an optimized race car.

II. LITERATURE REVIEW

2.1 Extent of Recent Work

EVs have appeared as a model of sustainability and respect for the environment, due to the fact they do not emit harmful substances into the air, unlike conventional internal combustion engine (ICE) vehicles (Stevan *et al.*, 2017). Such sustainability is not only limited to the usage of EVs, but also their design, the prime materials used in the manufacturing of these vehicles, and the energy footprint during their use (Habib & Kamran, 2014). EVs are being developed to reduce the toxic effects of harmful substances emitted from IC vehicles to achieve safer and more cost-efficient transportation networks.

Recent studies have shown that a lot of attention has been paid to the problem of designing and fabricating an EV. Many authors are professionally engaged in the design of lightweight EVs, the design, and fabrication of eco-friendly vehicles for physically handicapped persons, design and fabrication of foldable electric motor-powered three-wheel vehicles (Travis de Fluiter *et al.*, 2008; Swati *et al.*, 2018: Jayesh *et al* 2017). Cheng (2009) studied recent development in EVs. Kuseker *et al.* (2015) analyzed the design and development of EVs. Someswara *et al.* (2017) conducted the design and analysis of electric three-wheeler auto while Mohd *et al.* (2015) performed mathematical modeling and simulation of an electric vehicle and Sakamoto (2004) studied the designing and manufacturing of a hand-made electric motorcycle. Kaloko *et al.* (2011) carried out the design and development of a small EV using MATLAB/Simulink. Bharati *et al.* (2018) analyzed the design of a three-wheeler electric vehicle: a review while Husain and Islam (1999) conducted the design, modeling, and simulation of an EV system, Dhanashri *et al.* (2017) studied the design of a solar tricycle for handicapped people and David (2012) performed EV drive simulation with MATLAB/Simulink. Fuad *et al.* (2017) carried out A Comprehensive Study of Key EV Components, Technologies, Challenges, Impacts, and Future Direction of Development. Gowtham *et al*. (2020) conducted the design and analysis of all-terrain EVs and Aswathy *et al.* (2018) studied the design and analysis of an on-road charging EV.

Jayesh *et al.* (2017) carried out the design and fabrication of foldable electric motor-powered three-wheel vehicles. They stated that the population of the world is increasing and the area is decreasing. They added that the population is in the stage of a compact world, where all things are going to be compact, the time is to think about a vehicle that can be folded easily and can be taken everywhere. The basic aim behind their study was to make a portable vehicle that would be easy to handle by both genders and should emit 0% emission, also keeping in mind the parking problems. Their study decided to make a portable suitcase vehicle that can be folded easily. So after use, one can fold a suitcase and can carry it along with him or her as a suitcase and keep it at home or wherever there is a place for the size of a suitcase.

III. MATERIALS AND METHODS

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

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.

4.1.1 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.

4.1.2.1 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

IV. RESULTS AND DISCUSSION

4.1 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)

V. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

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.

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