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Design and Analysis of Different Components of Electric Scooter

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Abstract

The rise in the prices of petrol and diesel is leadingvehicles to be less cost-effective and low sustainable. Battery- powered vehicles are a promising and sustainable alternative that provides low-cost and emission-less drives. This paper concentrates on the analysis of Electric Scooter. The design of the chassis has been done using FUSION 360 and was assessed using an analytical tool such as ANSYS to obtain simulation results under different load conditions. The power required by the scooter has also been calculated for different speeds and loads and the optimal speed and power consumption were analyzed.

Keywords: Electric scooter, Battery, power;

1. Introduction

Commercial electric scooter was introduced in 1996 which used Ni-Cd batteries lasting up to 40km. Electricenergy is used to run the battery-powered e-scooter. A charger with a suitable rating is used to charge the batteries. Electric engines or motors convert electric energy into mechanical energy and are environmental-friendly, unlike combustion engines which emit harmful substances. E-Scooters provide a green and economical substitute and act as an important factor for socio-economic growth. Further in the paper, the design process of the chassis as well as a study regarding structural deformation and run time of the electric scooter is mentioned.

2. Literature review

The following are the conclusions for the previous worksperformed on the design and analysis of electric vehicles.

Gurugubelli et al. developed a motorcycle frame made oflow carbon steel to give the material tendency of strength, toughness, ductility, weldability, formability, and good wear resistance. The design of the chassis was done using Solidworks software. Similarly, Hariprasad et al. studied the crucial system of Battery management system in an electric vehicle. They also described the state of charge, state of life, and state of health of the battery. WIZ Energy Technology patented a dual battery system for electric vehicles in which benefits of two different batteries Lead-acid and Lithium are combined. The Lithium battery provides power into the lead-acid battery as well as motor to drive the vehicle under light load conditions. Lithium batteries can be removable to be able to charge them in any charging outlet. This decreases the risk of a dead lead-acid battery. Schalkwyk and Kamper hadcompared hub driven vehicle with a standard electric vehicle.They studied the stability and vibration of the system. They found that the stability of the vehicle and vibration were not affected by any added wheel mass. In another work, Patil andJoshi studied and reviewed static structural analysis of chassisof heavy vehicles or trucks were analyzed under finite element analysis. They used ANSYS for the static structural analysis. The results were also shown in form of a graph of member thickness versus Von-Misses Stress. They also mentioned that most researchers used ANSYS for FiniteElement Analysis. This research work has been taken todesign the chassis for the electric scooter and also to analyzethe performance of different components.

3. Components and Material Selection

A. Battery

A battery is an energy storage device that consists of chemical energy. When it is connected to a circuit the chemical energy is converted into electric energy and the circuit is powered. There are many types of batteries, in electric vehicles mostly lead-acid and lithium-phosphate batteries are used. Lithium-Phosphate batteries are used for high discharge in high-performance vehicles.

B. Controller

The Controller acts as a Carburetor. It is necessary for a BLDC motor, it ensures balance and proper flow of energy within the vehicle. It serves as the brain as it knows how much energy is needed by the motor to power the vehicle.

C. Motor

A BLDC motor is used which is prefitted in the hub of therear wheel hence reducing the need for extra transmission components. It converts 95% of the electric energy into mechanical energy as the rest 5% is lost due to heat. Unlike combustion engines which hardly give 50% efficiency. A 48V 1000W BLDC motor is used in this project.

D. Chassis

It is the structural foundation that holds all the components as well as withstands all the forces while running on the road.It is made up of structural steel to provide high strength. It bears all the stresses both in static and dynamic conditions.

E. Connection Wires and Electric parts

These are used to connect the above components (battery, motor, controller, etc) and are run through the chassis members. Lights and horns are used to make it safe to run onthe road.

4. Design and Anlysis

Chassis is the structural section of a vehicle that providessupport for all the components which are to be assembled. The transmission system, the wheels, and the steering are the primary components that are attached to the chassis through nuts and bolts. Chassis withstands all types of loads and stresses. While driving, the weight transfer takes place through the members of the chassis, in turn allowing a safe and smooth load distribution.

Structural Steel is used for the fabrication of the chassis. Structural steel is low cost compared to other materials, its weldability and ability to absorb impacts are generally produced due to irregular road surfaces. Its strength-to-weightratio is comparably high, hence resulting in a lighter vehicle and an improved overall efficiency.

Table 1: Properties Table- Structural Steel

Mechanical Properties	Values
Young's Modulus	2×10^5MPa
Poisons Ratio	0.3
Density	7850 kg/m^3
Thermal Expansion	12×10^{-6} $^oK^{-1}$
Tensile Yield Strength	250MPa
Ultimate Tensile Strength	460 MPa
Shear Modulus	81000 MPa

A. Design of CAD Model of Chassis

The Chassis of the electric-Scooter is designed using CAD software (Computer-Aided Designing Software) called FUSION 360.

Table 2: Design Specifications

Design Specification	Values
Length	1140mm
Width	220mm
Handle Height	1000mm
Head Tube Angle	27^{o}
Seat Height	665mm

Fig. 1 Chassis (Isometric)

B. Analysis of Chassis

The Chassis of the e-scooter is analyzed using a CAE software (Computer-Aided Engineering software) named ANSYS. ANSYS is a Finite Element Analysis tool utilized for simulations and studies. It is used as a solver for different engineering problems. Ansys helps us in visualizing the solution and provides us with accurate results. The model of the chassis was imported into Ansys mechanical to perform static structural analysis under different loads.

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C. Static Structural Analysis

In a structural analysis of the chassis the front and rear wheel mounts were set as fixed supports and a load ranging from 400N to 2400N is applied gradually on the mid members of the chassis.

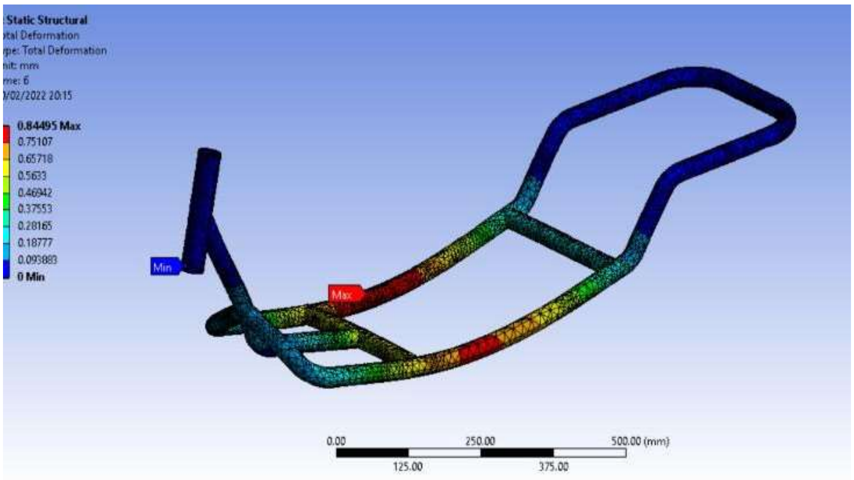

Fig. 2 Total Deformation

Fig. 2 indicates the deformation of the chassis and the location of maximum deformation is shown in the figure. Themagnitude of maximum deformation is found to be 0.84495mm. The maximum and minimum variation of the deformation of the chassis upon applying a certain load is indicated by various color zones. Here, the red zone is indicating maximum deformation and the blue zone is indicating the least deformation.

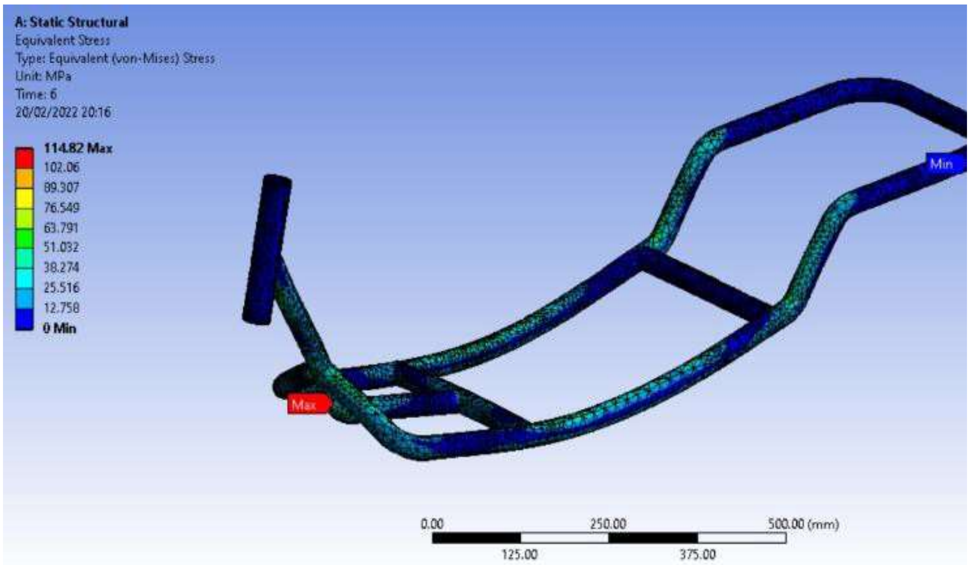

Fig. 3 Von-Misses Stress

Fig. 3 indicates the variation of equivalent Von-Misses Stress for a certain load parameter. The magnitude of maximum stress is found to be 114.82 MPa. Different color zones in the figure indicate different values of Von-Misses Stress which varies from maximum to minimum. The least value of Von-Misses Stress is given by the blue zone and found to be 0 MPa.

D. Design Calculation

Gross Weight = 120 kg × 9.81N = 1177.2N

Here, the mass of the vehicle that is 120 kg is considered to be the mass of the vehicle in addition to the driver load thatis considered under maximum operating conditions.

The maximum mass of the vehicle is considered to be 20 Kg and the maximum driver load is considered to be 100 Kg.therefore, the maximum overall mass of the vehicle is taken as 120 Kg.

Velocity = 40 km/h = 40× (1000/3600) = 11.11 m/s

Resistance against motion:

a) Hill climbing force:

$F_h = W \times \sin\varphi$ (1) (Angle of incline φ is 2.5)

= 1177.2× sin φ= 51.34 N

b) Rolling resistance:

$F_r = C_r \times W \times \cos\varphi$ (2) (for asphalt roads C_r=0.004)

c) Air resistance:

$F_d = 0.5 \times \rho \times C_d \times A \times V^2$ (3) (C_d= 0.5 for frontal area A=0.7 m^2)

= 0.5 ×(1.2) ×0.5 ×0.7×11.11^2 = 25.92 N

(ρ = 1.2 kg/m^3)

Total Resistance against motion,

$F = F_h + F_r + F_d$ (4)

= 81.96 N

Power for propulsion,

$P = F \times V$ (5)

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= 81.96 × 11.11 =910 Watt

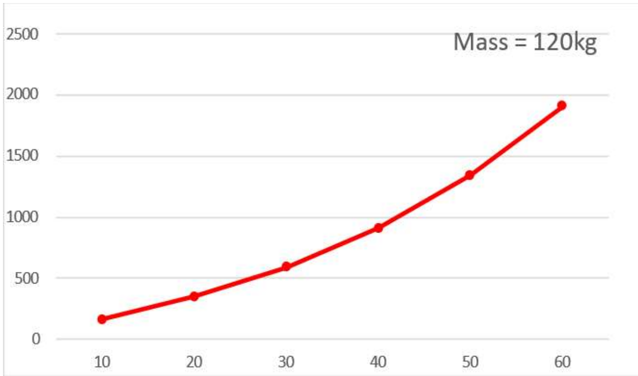

Fig. 4 Graph showing Velocity vs Power.

The graph indicates the variation of power for change in velocity parameter keeping mass constant. In the above graph, the velocity parameter is taken in X-axes and the power parameter is taken in Y-axes. For different values of velocitydifferent values of power are calculated and plotted in the graph as shown above.

E. Motor Specifications:

The total power required by the vehicle is found to be 910Watts. Hence to overcome that we have to use a motor ofpower rating higher than 910W. A 1000 watts BLDC hub motor will be enough to drive the vehicle at the required loadand speed.

Rpm of the motor is the rpm of the wheel which is 8inches.

$$\boldsymbol{V} = \boldsymbol{r} \times \boldsymbol{\omega} \qquad (6)$$

(r = 8 inch = 0.2032 m, ω= angular speed of wheel)

ω=11.11/0.2032= 54.68 rad/s

$$\text{RPM}= (60^* \omega)/2^* \boldsymbol{\pi} \qquad (7)$$

= 522.155~523

So, let's take motor rpm as 600.

A. Battery Requirement:

To run 1000W motor for 1 hr

Watt hour = 1000W * 1hrs = 1000Whrs

Watt hour required with 80 % efficiency of battery = 1000/0.8 = 1250W-hr

Voltage = 48 Volt

Current $= \frac{1250\ Whr}{48\ V}$ = 26.04 Ah

After compensating for the losses in battery, we need 26.04Ah capacity to run the motor for 1 hr under a maximumof load conditions. As a full 1000W of the motor is not used the run time of the motor will be more than 1 hr.

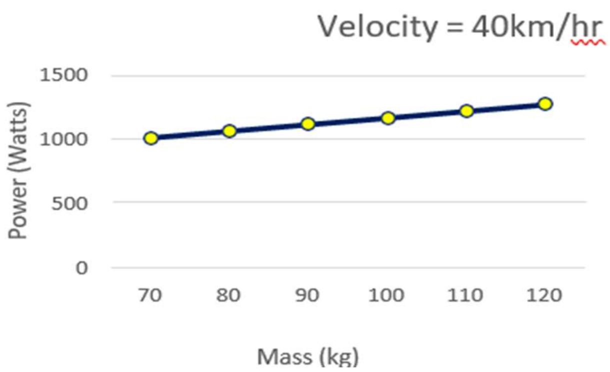

Fig. 5 Graph showing Weight vs Power

The above graph describes the variation of power for a change in mass of the vehicle keeping the velocity constant. In the above graph, Mass is taken from 70 kg under the assumption that the vehicle is 20 kg and the rest is the weightof the driver. For different values of Mass different values ofpower are calculated and plotted in the graph shown above.

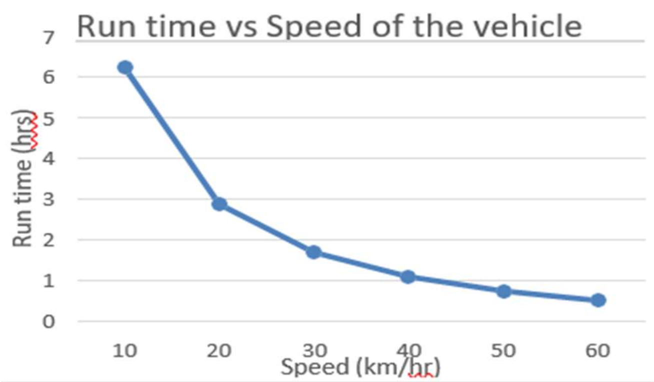

Fig. 6 Battery Performance with variation in speed of the vehicle

In the above graph, the battery losses are not under consideration. The graph shows that as the speed of the vehicle increases, the run time decreases significantly. We can observe that there is a steep drop in the run time of the motor from 10 km/h to 20 km/h after which the fall is gradual.

A. Charger Specifications:

Watt-hour = 1250W-hr Allowable charging time = 3 hrPower rating of

charger

= (Battery watt hour/ Preferred charging time)

= 416.67 watt

Charger voltage = 24 volt

Current rating = (Power rating of charger/voltage)

= 17.36 Amp

The preferred charger specification is 24V/17.36amps.

B. Motor Controller Specifications:

For the specified motor and battery specifications, the recommended controller is 48V with a power rating of 1000W.

4. Conclusions

Increasing use of domestic transport vehicles is a leadingcause of environmental pollution. Electric vehicles provide asustainable alternative. The paper provides an optimal designfor a low-end easy-to-use electric scooter. The power requirements and battery backup time for different speeds of the vehicle are briefly plotted and visualized through differentgraphs. A full charge gives 1hr of the runtime of the scooter under maximum speed (40kmph) and load (120kg). The runtime improves under normal conditions as maximal loadsare not always in use. Not only electric vehicles are good forthe environment but are also economical and have simple mechanics involved, research and innovation are undergoingto increase battery performance and decrease charging time. Hence, advancement is ensured and electric vehicles may completely replace other alternatives soon.

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