Structural Analysis And Working Of An Electric Scooter

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Abstract- *The proposed project aims toward analysis and further scope of development of electric two wheelers using FEM analysis and proposes modifications required for better efficacy, reliability and a user friendly interface. The electric two wheeler in this project uses a 48v 250 watt BLDC wheel hub motor powered by a setup of 4 VRLA sealed 12v-24ah/10hr lead acid battery setup and a vector sine wave controller. The vehicle also houses a DC-DC convertor setup to run its lighting and user interface systems. Currently, there are a profound number of electric two wheelers in the market but these are still not preferred over the usual IC engine vehicles. Primary reason being its non-user-friendly interface and unsatisfactory mobility. The project here aims to analyze the buildup quality of vehicle frame, hub motor and battery and also provides proposed solutions for further development of electric two wheelers*

Keywords- Electric, Two wheeler, Lithium, Battery.

I. INTRODUCTION

The two-wheeler market around us comprises of various vehicles and the ones powered by combustion technology are currently leading the market. The electric market in India is still at its embryonic stage and if pushed forward properly, can completely replace the combustion vehicle which is exactly what the planet demands. This research paper aims to analyze an electric two wheeler structurally and functionally and provides appropriate modification ideas for the future technology.The Navigant research forecast that worldwide sales of e-Two wheelers will rise to 6 million annually starting from 2015 to 2023, and this will total up the rapid increment in sales to 50 million, driven by rising fossil fuel prices and increasingly congested city streets, more consumers are starting to switch to two wheel vehicles, mainly focusing on electric Two wheelers.The main parts of electric scooter comprise of main frame, electric power-train (either chain drive or BLDC hub), rechargeable battery, battery charging system and motor controller. This type of electric scooter is easy to operate and light in weight as compared to IC engine two wheelers. Electric two wheelers are the future and are absolutely tautological and absolutely have the potential to improve local air quality and greenhouse emissions compared to IC two wheelers. They can also reduce noise pollution drastically which allows them to directly compete with gasoline two wheelers and over the time replace them entirely. They have a few limitations due to the current battery technology available to us. These include its average speed which takes a huge blow when the battery of the vehicle is low, not providing the initial pick up or thrust that it does when the battery is at a 100%. Secondly, its travel range, this can be seen as a limitation for people who have an average commute that is long ranged (80 to 100 km) and last of all, its charging time and low availability of charging stations.

II. LITERATURE REVIEW

While going through research papers for gaining knowledge about the concept and developing ways of understanding and methods of carrying out project many different papers were taken into consideration following are the some of the papers and taken into consideration for collecting knowledge

Electric two wheelers in India and Vietnam, market analysis and environmental impacts, By Asian development bank

A variety of e-Two wheelers are emerging as alternate mode of transportation that saves energy and is eco-friendly. Electric Two wheelers are much cleaner than gasoline powered two wheelers and counterpart on most merits. Gasoline two wheelers produce 2 times the CO2, an order of magnitude more nitrogen oxide gases and particulate matter 10, and several order of more volatile organic compounds and carbon monoxide. Particulate matter 2.5 and Sulphur dioxide emissions unknown for gasoline vehicles, but electric Two wheelers could have higher emission rate of these pollutants due to their reliance on fossil fuel power plants. Electric two wheelers in India have higher emission rate than those in other countries e.g. VIETNAM, because of INDIA'S higher reliance on coal power plants and higher electricity transmission rates given existing policy environment and technology electric Two wheelers can be expected to fill up 20% of market surrounding us in INDIA. Given technological improvements, supportive tax policy, and increased gas prices market shares can exceed 40% of market. a strong preference for gasoline two wheelers, regardless of price and, indicates that electric two-wheeler industry government and non-government organizations should engage in marketing, and

public awareness aside from developing supportive two-wheeler policy.

[1]Design and development of multi- utility electric scooter using hub motor transmission, by Prof. Firoz Khan, Sharat Kumar, Prashant S, Vikas B.

This project aimed at development of light weight multi-utility e-scooter, which carried out different design and analysis procedure which helped in achieving project objective.

The e-scooter developed was able to perform versatile material handling operations.

2]Designing of vibration analysis of scooter chassis by, Mr. Barister Giri Prof. Shah B. R The researcher has been made an effort to investigate the vibration analysis of scooter chassis.

The analysis performed while doing research are of two types one static and other one is dynamic. The researcher has also made an effort to prove a validity of experimental and analytical results for two-wheeler chassis for reduction in vibration. The chassis is considered to be one of the vital elements in building a vehicle and it is backbone of the any vehicle, as all other components attached to it. The movement of parts is always resulting in the vibration and according to well- known rule of vibration “lesser the vibration better is the design”. In this paper researcher has made an effort to model a scooter chassis in CATIA, CAD, Hyper mesh and ANSYS for various analysis and optimization of the model

[3]Structural and modal analysis of scooter chassis, by D. Mohankumar, R. Sabarish, DR.M. Premjeyakumar

This project discusses the stress and deformation developed in chassis during the different load cases and also failure modes by modal analysis. This paper follows benchmark study of different scooter frames in aspect of material selection, mechanical properties and sections used in it.

III. PROBLEM STATEMENT

For purpose of understanding of e-Two wheelers, a market developed was chosen, the model of scooter was Ampere REO which is a product assembled in INDIA which uses Chinese technology, It comprises of a 250-watt 48-60 v wheel hub motor, a 4 sealed VRLA 12v-24ah/10 hr. battery setup connected in series, to generate 48-volt supply for motor, a Vector sine wave controller setup, a AC-DC charger and e-scooter chassis as its basic components. When bought the scooter was not in running condition as one of the battery cells was dead due to long unused condition. The faulty battery cell was replaced with a second hand battery cell of same company. For understanding e scooter much better let in brief understand the basic components of an e scooter.

IV. COMPONENTS OF E SCOOTER

250-Watt wheel hub motor:

Ordinary electric motors use a mechanical device called a commutator and two contacts called carbon brushes to reverse the electric current periodically and ensure the axle keeps turning in the same direction.

Hub motors are typically brushless motors (sometimes called brushless direct current motors or BLDCs), which replace the commutator and brushes with half-a-dozen or more separate coils and an electronic circuit. The circuit switches the power on and off in the coils in turn creating forces

Figure 4.1 250-WATT BLDC HUB MOTOR

in each one that make the motor spin. Since the brushes press against the axle of a normal motor, they introduce friction, slow it down, make a certain amount of noise, and waste energy. That's why brushless motors are often more efficient, especially at low speeds. Getting rid of the brushes also saves having to replace them every so often when friction wears them down.

In a normal motor, you'd expect the inner coil to rotate (it's called the rotor) and the outer magnet to stay static (that's called the stator). But in this motor, the roles are reversed: the inner part with the coils is static and the gray magnet spins around it. If we look inside and you can see exactly

how it works: the electronic circuit sends power round the nine copper coils in turn, making the gray outer case (which is a magnet split into a number of sections, bent round into a circle) spin around the copper coils and circuit board (which remain static).

There are several tiny magnetic field sensors (known as Hall-effect sensors) positioned between some of the coils. As the permanent magnets on the outer rotor sweep past them, the Hall-effect sensors figure out where the north and south magnetic poles of the rotor are and which coils to activate to make it keep spinning. The trouble with this is that it means the motor does need an electronic circuit to operate it, which is something you don't need for an ordinary DC motor.

Hub motors are bigger, bulkier, and heavier than ordinary wheels and change the handling of an electric car or bike: they increase the unsprang mass (the mass not supported by the suspension), giving more shock and vibration, poorer handling, and a bumpier ride.

The motor present in the e scooter bought is 250-watt 48-60 v wheel hub motor.

Battery:

Battery is the major supplier of electricity to electrical system Two wheelers. It is a device that converts chemical energy into electricity. Without battery, electric Two wheelers wont function. Batteries are of two types which are rechargeable and disposable batteries. Electric Two wheelers usually use rechargeable batteries because they are more durable and reliable.

Figure 4.2 12 V-24AH/10HR

For the above-mentioned Battery scooter, the battery setup consists of 4 VRLA 12v-24ah/10hr batteries which are sealed lead acid batteries connected in series to provide 48v output for motor.

The types of rechargeable batteries are: -

- Sealed lead acid battery (SLA)
- Nickel cadmium battery (NiCad)
- Nickel metal hybrid battery (NiMH)
- Lithium -ion battery
- lithium - polymer battery

Lead Acid:

This type of battery is used in conventional car also for the starting, ignition, lighting and other electrical function. This type of battery was used during the earlier time of EV technology. It is relatively inexpensive however the built of this battery is too heavy and suffer an insufficient range for EV application.

Nickel-Metal-Hydride (NiMH):

Currently, this type of batteries is among two leading battery used for EV. It is widely used in hybrid EV due to its ability to hold energy far more than lead-acid, much longer life cycle and lighter weight compared to lead-acid. In hybrid EV, the power source for the vehicle is either from an internal combustion engine or electric motors. This battery has higher self-discharge rate and capable to deliver rapid power burst. However, the battery's cycle life will be reduced if it has experienced repeated rapid discharges with high load in order to give rapid power burst. Therefore, this type of battery is more suitable in hybrid EV application rather than battery EV which typically experiencing deep discharge cycles.

Nickel-Cadmium (NiCad):

NiCad battery have longer life cycle as it can tolerate deep discharge cycle longer than NiMH. It is also lighter in weight compared to lead-acid. However, this battery suffered low relative electrical capacity. The low capacity of electric may cause melting or burning of battery if it experiences deep discharge and quick charging in short of time. Unlike NiMH, it also has disadvantage of having "memory problem" or memory effect. The memory problem happens when the battery is repeatedly recharged before it has been completely discharged.

Lithium Ion (Li-ion):

The Li-ion battery is one of the two leading battery used in the EV technology aside from NiMH. This type of battery wins over Nickel chemistries due to several factors which include more energy capacity in much lighter package, low in self-discharge and good temperature performance. And the good news about Li-ion is the environmentally friendly factor where almost all parts of battery components are recyclable. Due to all the good qualities, the battery comes with more expensive cost compared to all other battery types.

Despite that, Li-ion is still a preferred choice for most of hybrids and battery EV.

Ultra-capacitors:

Ultra-capacitors store energy in a polarized liquid between an electrode and an electrolyte. Energy storage capacity increases as the liquid's surface area increases. Ultra-capacitors can provide vehicles additional power during acceleration and hill climbing and help recover braking energy. They may also be useful as secondary energy-storage devices in electric-drive vehicles because they help electrochemical batteries level load power.

There are three major consideration for choosing this battery: -

- Cost
- Performance for a given application
- Environmentally friendly

The battery setup has a charging time of 6-7 hours, and has efficiency to run motor for 40 km when fully charged. The battery chosen for this scooter has certain limitations of which are longer charging time, does not have swappable application option, heavier as compare to other batteries and also does not store enough charge as other batteries. Another option for this scooter can be lithium-ion batteries I would require less charging time and also since has more charge storing capacity can run motor for more 10-20 kms if battery size is same, and also it has swappable option when discharged.

Vector sine wave controller:

This is the brain of the electric scooter it takes input from user and provides required signals for motor using charge on battery, it also helps in providing 120 degrees phase shift between rotor poles, it senses signals from hall sensors attached on hub motor poles which help in modulation of current according to required phase angle. It also helps in cutting off current while braking as it may cause heavy load on motor. It modulates signals from throttle (i.e. potentiometer), it is also source supply for DC-DC converter which runs scooter's peripheral systems such as lighting, horn odometer etc.

Fig 4.3 Vector Sine Wave Contoller.

Scooter chassis:

The two-wheeler chassis consists of the frame suspension, wheels and brakes. The chassis truly sets the overall style of the two-wheeler. Chassis frame can be made up from steel, aluminum or an alloy and nowadays also composite materials which will be further tested in project. It is necessary that frame should not buckle on uneven road surfaces or other distortion which should not be transmitted to body. The frame must be thus torsion resistant. The frame mostly consists of hollow tubes on which other equipment's are mounted.

Figure 4.4 side view of e-scooter

V. METHODOLOGY

The above scooter was restored for smooth running and was further used for analysis of its frame structure and also trying to increase its body stiffness by using different materials for its CAD and FEA static structural analysis. The below fashion of work procedure was followed during developing its CAD using CREO 5.0 software and its structural & Modal analysis in ANSYS 19.0.Benchmark of scooter frame for tube thickness, diameter and mounting position of brackets along with thickness were taken. Knowledge of material property of scooter frame and other parts were taken in consideration. Required design calculations and parameters were assumed. The frame structure was modeled in CREO 5.0 modeling software. The Finite Element Meshing was carried out in ANSYS 19.0 and

also required material. Properties were defined in same. The meshed models were taken for solving in ANSYS solver. The required results were recorded and the frame was analyzed according to it.

Development of 3D Model:

Creating the accurate model is the first step in finite element process; it stands to a reason that if the model does not accurately represent the object then the analysis will be incorrect. Special care has to be taken for modeling objects if they were to be used for FE meshing operations. The dimensions of chassis have been extracted from existing one by using reverse engineering. Dimensions are required for calculating of boundary conditions. Hence its CAD model is necessary. Dimensions are taken through reverse engineering i.e. through hand calculations.

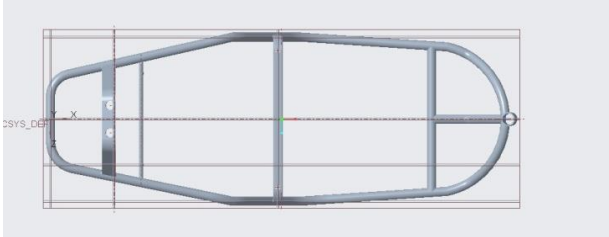


Figure 5.1 Top View

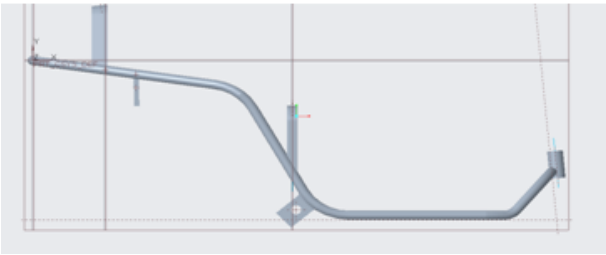


Figure 5.2 Right Side View

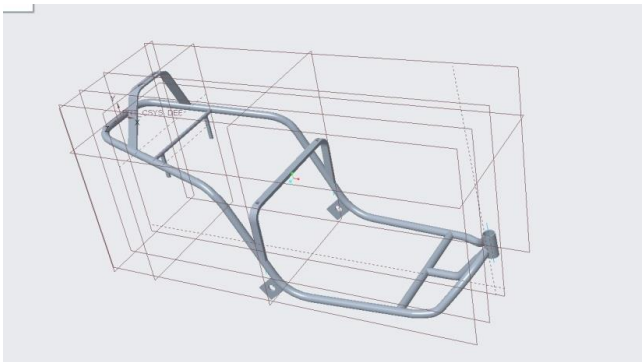


Figure 5.3 perspective view

Fundamentals of FEA:

The FEA is the process to a part assembly to ensure product integrity over the product lifetime. FEA allows the engineers to simulate structural behavior, make design changes and see the effect of design changes quickly and automatically. Meshing is the ability to subdivide geometry into series of discrete elements, which helps in deep analysis of objects. After creating the CAD model of frame structure in CREO, the frame geometry was imported for simulation process to ANSYS software. 4 different material were used to compare its strength ability with the original mild steel material.

Following were the materials used: -

- Structural steel
- Carbon fiber
- PVC foam
- Stainless steel

After defining Material properties, the geometry was applied with its constraints of load and support, The assumed load of 240 kgs was consider which include rider with pillion and other weight components of the analysis project. Different materials were tested and their respective results were compared and analyzed. The results comprised of total deformations and areas of max principal stress. The different materials were also tested with modal analysis in ANSYS which will help in optimization of material selection for building up of scooter chassis.

Static Structural analysis:

A static structural analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time. A static structural load can be performed using the ANSYS, Samcef, or ABAQUS solver.

Modal analysis

Modal analysis is an efficient tool for describing, understanding, and modeling structural dynamics. The Dynamic behavior of a structure in a given frequency range can be modeled as a set of individual modes of vibration. The modal parameters that describe each mode are: natural frequency or resonance frequency, (modal) damping, and mode shape. The modal parameters of all the modes, within the frequency range of interest, represent a complete dynamic description of the structure. By using the modal parameters for

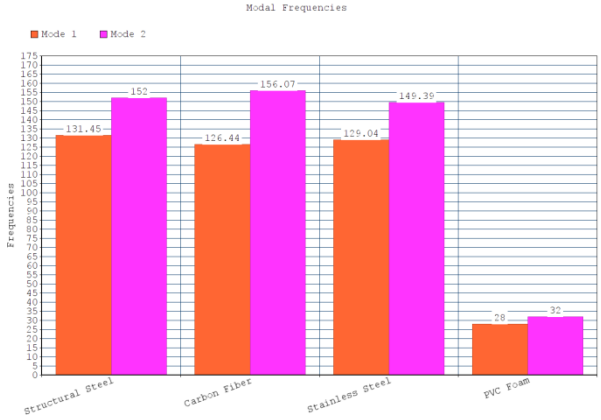
the component, the model can subsequently be used to come up with possible solutions to individual problems. Modal frequency response analysis is an alternative approach to determining the frequency response of a structure. Modal frequency response analysis uses the mode shapes of the structure to reduce the size, uncouple the equation of motion (when modal or no damping is used), and make the numerical solution more efficient. Due to the mode shapes are typically computed as part of characterization of the structure, modal frequency response analysis is a natural extension of a normal mode analysis.

VI. RESULTS AND CONCLUSION

Conducting modal analysis and tests for deformation on the following materials, these were the results obtained.

Modal Frequencies

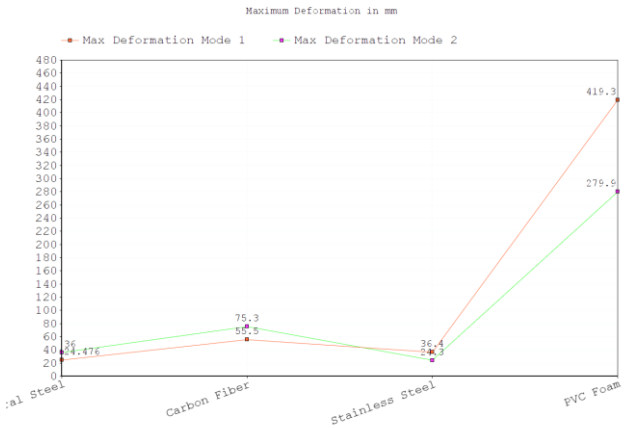
Structural steel: 131.45 and 152
Carbon Fiber: 126.44 and 156.07
Stainless Steel: 129.04 and 149.39
PVC Foam: 28 and 39



From the above data table one can easily understand that carbon fiber and stainless steel are two materials whose mode frequencies lie nearest to human comfort levels. [1]

Maximum Deformation in mm

Material	Max Deformation mode 1	Max Deformation Mode 2
Structural Steel	24.476	36
Carbon Fiber	55.5	75.3
Stainless Steel	36.4	24.3
Pvc Foam	419.3	279.9



From this table one makes out that the competition for carbon fiber and stainless-steel wins by scorings against carbon fiber due to less deformation which increases frame life and make the body stiffer.

The above analysis showed the material carbon fiber showed best results against all in static structural analysis but failed in Modal analysis. Comparing all the materials in both the analysis showed that Best suitable for making of frame structure is stainless steel as it possesses both load and vibration resistance capabilities and also helped in developing opinion on design modification required. But the material has one limitation i.e. it's making cost and chassis fabrication cost.

VII. FUTURE SCOPE

Electrical vehicles are considered as the future of next generations since it uses electrical energy, since other fossil fuels are depleting,

The further analysis of frame can be continued plotting its modal analysis and also using the whole scooter assembly for analysis.

New innovations have to set up in building up a user interactive and friendly interface which could be developed using led displays and other function capabilities such as: -

- Built in Navigation system.
- Battery charge and discharge monitor
- Theft protection system
- AI learning capabilities
- Applying concept of regenerative braking in two wheelers
- Swappable batteries system for ease of access to user

Different materials should be considered for developing new frames which will be light in weight. And development in new charging system should be developed which uses concept of solar, wind and piezoelectricity energy generation system.

The solar energy for charging the battery is the best alternative and this can be implemented by changing the design of the vehicle, by using suitable solar energy panels suitable for power generation.

REFERENCES

[1] P. S. Prof Firoz Khan, "Design and development of multiutility electric scooter using hub motor transmission," International journal of engineering research and techology , vol. 5, no. 07, p. 4, 7 july 2016.
[2] P. B. giri, "Designing of vibration analysis of scooter chassis," international journal of research publictions in engineering and technology , vol. 2, no. 3, p. 4, 2016.
[3] D.mohankumar, "Structural and modal analysis," International journal of pure and applied mathematics, vol. 118, no. 18, p. 10, 2018.
[4] S. R. A. Hanif, "Electric vehicle battery modelling and performance comparision in relation to range anxiety," Elsevier, vol. 1, no. 12, p. 6, 2015.
[5] W. Gruber, "Design and Implementation of a Wheel Hub Motor for an Electric Scooter," Institute of Electrical Drives and Power Electronics, Johannes Kepler University of Linz Altenberger , vol. 1, no. 1, p. 6, 2010.
[6] M. S. GUPTA, Automobile engineering, mumbai: S. Chand publishng , 2013.
[7] M. V. Bhandari, Machinbe elements, new delhi: tata McGraw Hill education pvt ltd , 2010.