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Design and Development of Compact Three-Wheeled Foldable Electric Moped

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***Abstract*-As, on road pollution is increasing day by day along with the growth of population, the need of alternative source of transport which can help surfing easily in crowdie areas and produce zero on road pollution is emerging. So this paper discuss in detail about design, fabrication methodology and characteristics of compact three-wheeled foldable electric moped. It also discuss in detail about the main components of this electric moped and its working operation.**

INTRODUCTION

The 1960s and 1970s saw a need for alternative fueled vehicles to reduce the problems of exhaust emissions from internal combustion engines and to reduce the dependency on imported foreign crude oil. During the years from 1960 to the present, many attempts to produce practical electric vehicles occurred and continue to occur.

The first EV (Electric Vehicle) was built between 1832 and 1839, in Scotland by Robert Anderson.

First Electric tricycle was built in 1895 by A L Ryker and William Morrison.

Electric vehicles are considered to be 97% cleaner, producing no tailpipe emissions that can place particulate matter into the air. Particulate matter, carcinogens released into the atmosphere by gas-powered vehicles can increase asthma conditions as well as irritate respiratory systems while EV does not create any such problems.

Three-wheeled EV enable people with certain disabilities to transit independently.

Also in extremely dense populated settings where EV are mostly used, traffic congestion means this agility is an important in terms of reducing trip times. They also don't require gasoline and since they are a light vehicle with a low power demand, recharging them is within a budget of many people. E-mopeds emit substantially less pollution per km than cars based on life cycle emission analysis.

Indian two-wheeler industry has embraced the new concept of electric bikes and scooters that are very popular mode of personal transport in the developed countries like America, Japan and China. With the rising cost of fuel at international and national level, increasing levels of population and congestion in transport system especially in urban areas, higher running and maintenance cost of vehicle, the electricity charged mopeds have very bright future in area of personal transportation.

The face of auto industry, which was redefined with the invention of fuel-efficient four stroke engine technology, is all set to see dawn of a new era in two wheeler industry. It's not petrol or diesel or any other fuel, but its electricity that have initiated a revolution in two wheeler industry.

The two-wheeler market has recently received further blow after the decision of price hike taken by Organization of Exporting Countries (OPEC) along with rising trend of inflation (more than 10%). Both these issues have opened

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new avenues for battery operated bikes that are getting popularity, known as E-mopeds (Electric mopeds). E-mopeds are based on power technology wherein rechargeable batteries replace the conventional engine. E-mopeds can be charged easily as a mobile phone. Moreover, we do not require a license to ride E-mopeds. It is quite clear that this is environment friendly that provides smooth and safe drive.

This project is another step towards the development of electric vehicle scenario. This e-moped is having features like folding mechanism for solving parking problems, three wheels for better stability and compact size which helps surfing easily in crowdie areas.

MAIN COMPONENTS

The main components of compact three-wheeled foldable electric moped are:

BLDC Hub Motor [1]: A typical brushless motor has permanent magnets which rotate around a fixed armature, eliminating problems associated with connecting current to the moving armature. An electronic controller replaces the brush/commutator assembly of the brushed DC motor, which continually switches the phase to the windings to keep the motor turning. The controller performs similar timed power distribution by using a solid-state circuit rather than the brush/commutator system. In hub motors, the axle is held firm so it can't rotate and whole motor start to rotate.

Brushless motors offer several advantages over brushed DC motors, including more torque per weight, more torque per watt, increased efficiency, increased reliability, reduced noise, longer lifetime. With no windings on the rotor, they are not subjected to centrifugal forces, and because the windings are supported by the housing, they can be cooled by conduction, requiring no airflow inside the motor for cooling. This in turn means that the motor's internals can be entirely enclosed and protected from dirt or other foreign matter. The efficiency of BLDC motor is 84%.

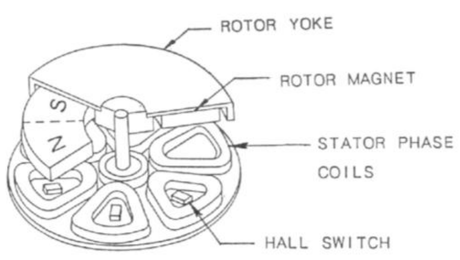

Fig. 1 Construction of hub motor

Controller [1]: Controller is the heart of an electric vehicle, and it is the key for the realization of the high performance vehicle with an optimal balance of maximum speed, acceleration performance and driving range per charge.

The controller connects the power source (battery) to the actual motor. It controls speed and direction and optimizes energy conversion. Controller generally controls the ratio between torque and speed. Torque is controlled by controlling armature current and speed is controlled by controlling armature voltage. Voltage control is achieved by chopping source current- the voltage is switched on and off, with the ratio of on-to-off determining the average voltage. The number of constant-width "on" pulses per unit time can be varied, or the width (duration) of the pulses can be varied. Chopping is performed by power electronics circuitry-diodes and thyristors and silicon control rectifiers (SCRs). Controller efficiencies are typically greater than 90%.

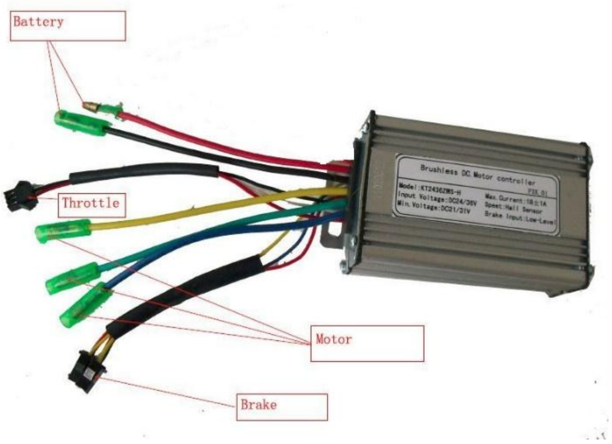

Fig. 2 Controller

Lead Acid Battery [1]: The lead-acid battery is the oldest type of rechargeable battery. Despite having a very low energy-to-weight ratio and a low energy-to-volume ratio, its ability to supply high surge currents means that the cells have a relatively large power-to-weight ratio. These features along with their low cost, makes it attractive for use in motor vehicles to provide the high current required by automobiles.

The main active materials required to construct a lead-acid battery are:

1. Lead peroxide (PbO_2).
2. Sponge lead (Pb) and
3. Dilute sulfuric acid (H_2SO_4).

In the discharged state both the positive and negative plates become lead (II) sulfate (PbSO4) and the electrolyte loses much of its dissolved sulfuric acid and becomes primarily water. The discharge process is driven by the conduction of electrons from the negative plate back into the cell at the positive plate in the external circuit.

Negative plate reaction (Oxidation):

$$Pb(s) + HSO_4\ (aq) \rightarrow PbSO_4(s) + H^+\ (aq) + 2e^-$$

Positive plate reaction (Reduction):

$$PbO_2(s) + HSO_4\ (aq) + 3H^+\ (aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O\ (l)$$

The total reaction can be written as

$$Pb(s) + PbO_2(s) + 2H_2SO_4\ (aq) \rightarrow 2PbSO_4(s) + 2H_2O\ (l)$$

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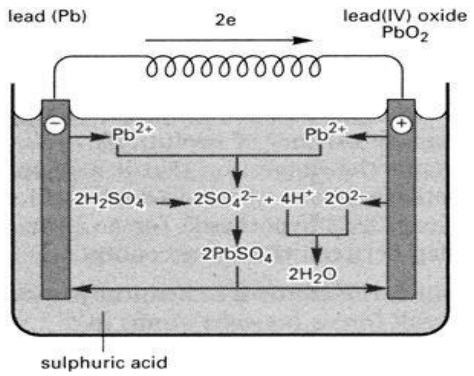

Fig. 3 Reaction process in lead acid battery

THEORY OF OPERATION OF ELETRIC VEHICLE [5]

When the driver accelerates the wrist throttle the potentiometer activates and provides the signal that tells the controller how much power it is supposed to deliver. The controller reads the setting of the accelerator pedal from the potentiometers, regulates the power accordingly, takes the power from the batteries and delivers it to the motor. The motor receives the power (voltage) from the controller and uses this power to rotate the wheel and causes the vehicle to move forward.

If the driver accelerates the full throttle, the controller delivers the full battery voltage to the motor. If the driver takes his/her hand off the accelerator, the controller delivers zero volts to the motor. For any setting in between, the controller chops the battery voltage, thousands of times per second to create an average voltage somewhere between 0 and full battery pack voltage.

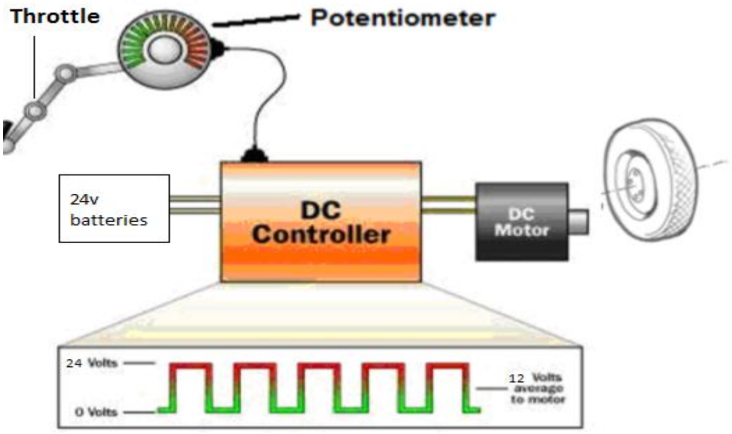

Fig. 4 Working Diagram of electric vehicle

METHODOLOGIES

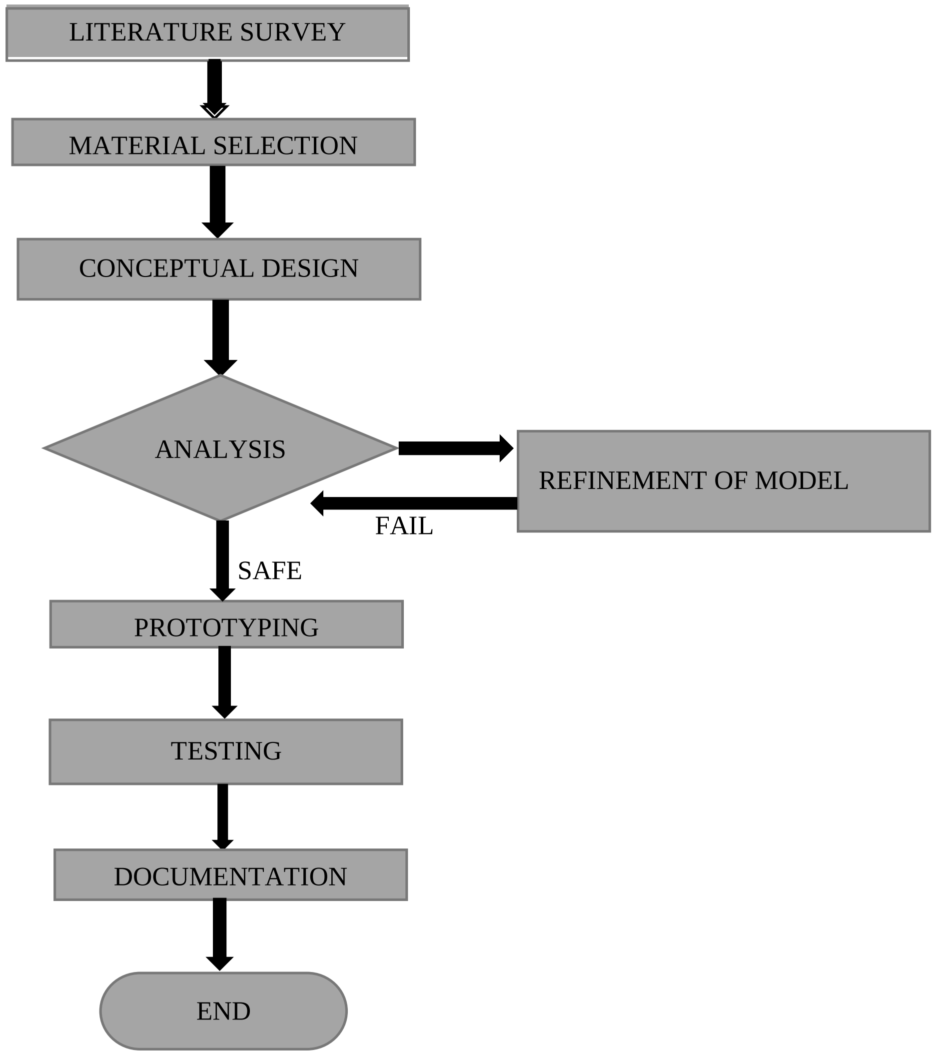

Fig. 5 Methodology Flowchart

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i. Literature study
Make review on other model and focusing on how to make it simple and relevance to the project title.
ii. Materials selection
Select the suitable material.
Light, easy to join and easy to manufacture.
iii. Conceptual design
Sketching the design based on concept that being choose.
State the dimension for all part.
Draw the sketching model using CREO2.0 or other modelling software.
iv. Computer Aided Engineering (CAE) analysis
Analyze the design for strain stress structure by using ANSYS
Define critical points.
v. Refinement of the model
In ANSYS if some of the parts are under stress strain failure then refine the dimensions of the model.
vi. Prototyping Development
Assemble all the parts to the design.
vii. Testing
Run the model
viii. Documentation
Prepare a report for the project.

SPECIFICATIONS

The specifications of compact three-wheeled foldable electric moped are:

1) Motor	BLDC Hub Motor 250W Weight – 7 kg Hub Dia. – 10” Cost – Rs. 15000
2) Battery	Lead Acid 2 (12v, 7Ah) in series Charging Time – 2 hr Cost - Rs. 1500
3) Controller	BLDC hub motor controller Cost-Rs. 1500
4) Material	Mild Steel (SAE 1018) UTS: 450 MPa YS: 250 MPa Young’s Modulus: 210 GPa Poisson’s Ratio: 0.3 Cost-Rs. 550
5) Wheels	3 Wheels of 12inch diameter each Cost- Rs.840
6) Brakes	Disc Brakes Disc Dia. 160mm Braking Distance 1.6 m(at top speed) Cost – Rs. 640
7) Top Speed	13.17 kmph
8) Range	18 km
9) Weight	23 kg
10) Track Width	350 mm
11) Wheel Base	700 mm

Table 1: Vehicle Specification

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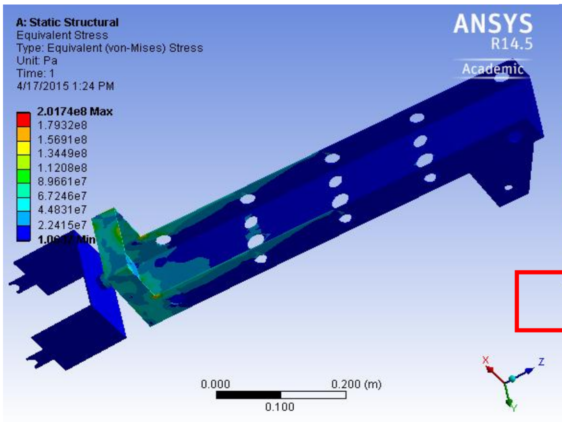
RESULT AND DISCUSSION

The material used for making a chassis is mild steel (SAE 1018) which is having a young's modulus of 210 GPa. Its analysis by applying various constraints and load was performed on the ANSYS software.

ANSYS of the front member



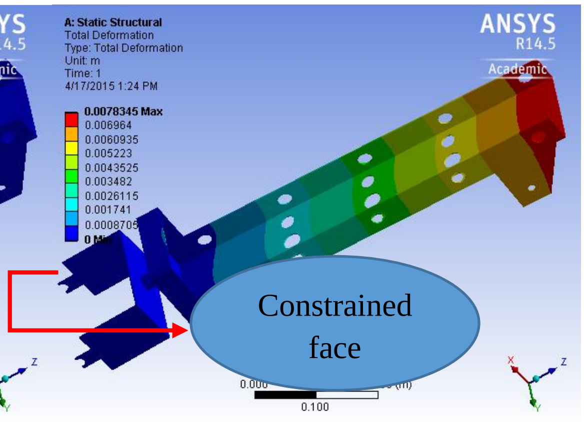
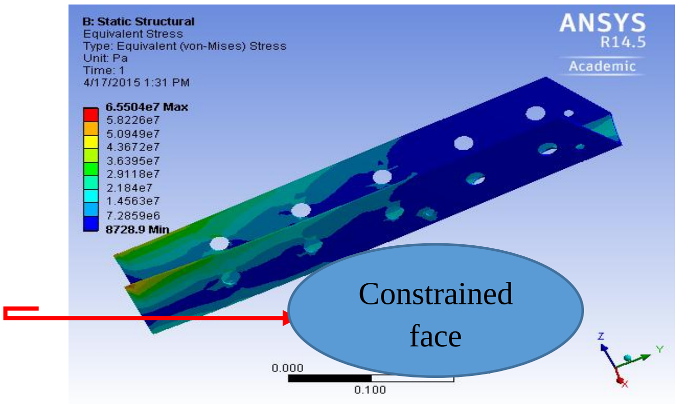


Fig: 6 Stress Plot of Front Member Fig: 7 Deflection Plot of Front Member

- Pressure applied on the front face is 17448 Pa. (Considering pressure of impact force at top speed of 13 kmph).
- Bottom face of member is constrained.
- Factor of safety 1.24 is achieved.
- Maximum deflection is 7 mm.

ANSYS of the rear member



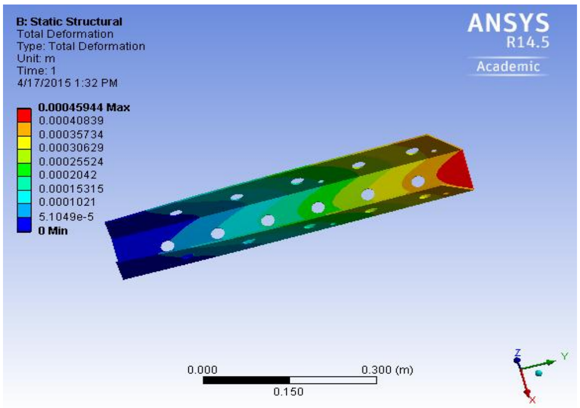


Fig: 8 Stress Plot of Rear Member

Fig: 9 Deflection Plot of Rear Member

- Force applied is 1710 N at the top. (Considering impact force at top speed of 13 kmph).
- Pressure applied at the rear face is 16.94 MPa. (Considering pressure due to weight of a person of 80 kg and mopeds own weight).
- Bottom face is constrained.
- Factor of safety of 3.78 is achieved.
- Maximum deflection is 0.45 mm.

Looking at ANSYS results of both the member one can say that it is very much safe to use mild steel (SAE 1018) as chassis material. It is having a good strength which reduces the chances of failure of the material.

Along with the structural strength the other most important parameters of any e-moped are its maximum speed, maximum acceleration and its braking distance. For finding this parameters testing was done on plane asphalt road having coefficient of static friction = 0.75, and coefficient of rolling friction = 0.02. Inclination of the road was 3^0. Person sitting on a moped was weighing 62kgs.

With above these constraints following results were obtained:

Speed

SR. NO.	DISTANCE (m)	TIME (sec)	SPEED (kmph)
1	3	1.7	6.35
2	6	2	10.8
3	9	2.5	13
4	12	3.3	13.03
5	15	4.15	13.17

Table 2: Speed Test

Acceleration

SPEEDS	TIME REQUIREMENTS	RUN 1	RUN2	RUN3	RUN4	ACCELERATION (m/s)
0-5	1sec	1.38	1.38	1.3	1.35	1.38
0-10	1.6sec	1.736	1.736	1.736	1.736	1.736
0-13	2sec	1.805	1.805	1.641	1.805	1.805

Table 3: Acceleration Test

Braking Distance

SPEED	STOPPING DISTANCE FOR RUN 1	STOPPING DISTANCE FOR RUN 2	STOPPING DISTANCE FOR RUN3	AVERAGE
13 KMPH	1.6m	1.6m	1.6m	1.6m
10 KMPH	1.2m	1.2m	1.2m	1.2m
8 KMPH	0.9m	0.9m	1m	0.9m

Table 4: Braking Test

Based on the testing, maximum speed, maximum acceleration and braking distance (at top speed) achieved is 13.17 kmph, 1.805 m/s and 1.6m respectively. Generally speed range of e-mopeds working on 250watts motor and 24v 7ah battery varies from 17 kmph to 21 kmph and acceleration range varies from 2 m/s to 3 m/s. Since testing was done on inclined road of 3^0 and radius of wheels are quite small, little deviation from desired value is obtained. Value of braking distance obtained is very much satisfactory.

CONCLUSION

As seen in this report, with 18 km range on a single charge, a top speed of 13 kmph and an ability to fold small enough to fit next to you in a train or a bus, it can act as an awesome last kilometer commuter vehicle and also it is great way of transport for short distance and crowdie areas.

It has many beneficial features such as folding mechanism, shock absorbing seat for an extremely comfortable ride, three wheels for more stability and disc brakes for better braking performance.

The electric moped has many advantages and it is cleaner and much more efficient.

Electric mopeds also eliminate the dependency of foreign imported crude oil hence helps in developing the economy of the country.

It also produces zero tailpipe emissions hence reduce the health hazards like cancer, asthma and various other respiratory problems.

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