# "Design and Development of an Electric Scooter kit which can be used to replace the IC engine"

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**Abstract -**The automotive industry is changing over period of time by concerns over Environmental, oil supply, international policy and fossil-fuel price. Government is now attracting consumers towards Electric vehicles by giving various subsidies on the tax while buying them. But a new question arises that "what about the old vehicles that are being scrapped because of the Scrapping policy, introduced by the Indian government in 2008?" Among them, the maximum vehicles are 2 wheelers. Our project aims to rebuild the old scooters that are been declared as scrap into an electric scooter. This would involve designing various parts (like swing arm, suspension, battery and module compartment, etc.) to rebuild the scooter and manufacture it. This would also involve testing the vehicle in the real world condition.

***Key Words*:** Electric vehicles, electric scooter, suspension, swing arm

## 1. INTRODUCTION

As we know that automotive industries are shifting towards electric vehicles and in following year's combustion vehicle are on the verge of termination due environmental effects and extinction of fossil fuels. People from all over the world are buying electric vehicles but what about the old vehicles? The electric vehicle cost more than combustion vehicle in market and also there is long process in selling your old combustion vehicle. The purpose of our project is to modify the old combustion vehicle into an electric vehicle this will save your time as well as money and increase the reliability and reduce the wastage of material.

Our project aims to rebuild the old scooters that are been declared as scrap into an electric scooter. This would involve designing various parts (like swing arm, suspension, battery and module compartment, etc.) to rebuild the scooter and manufacture it. This would also involve testing the vehicle in real world conditions. The purpose of designing and developing electric scooter using hub motor transmission is aiming at developing an electric vehicle which is reliable for customers use, multipurpose operations such as carrying goods and also for short distance transportation. Scooter makes the customer experience much simple while driving it and the project is also economical which makes it more affordable.

Looking at the scenario in the Indian Automotive industry, our aim will be build a vehicle electrification kit. This kit will involve various components such as Controller, Battery, Hub Motor, etc. considering all the models of vehicle available in the market; this kit will be compatible with all the models. One can easily convert his or her vehicle into electric using this kit.

## 2. Objectives-

1. As we know that any vehicle is valid for 15 years and after that we have to sell it into the scrap. As of now automotive industries are shifting towards electric vehicles. Our project aims to rebuild the old scooter into new electric scooter.
2. Our project follows Reduce, Reuse and Recycle principle. We are going to manufacture electric scooter by replacing the engine of old scooter by battery and hub motor.
3. It will be going to reduce the material wastage and also money, we are going to use chassis of old scooter and modify it into electric scooter. Our project aims to build a light weight, multipurpose scooter for short range distance.
4. We are going to design the suspension system, battery storage space, swing arm etc.
5. This scooter is design for short range applications for bringing essential goods or to go somewhere nearby one locality.

## 3. System Development-

As we know in an electric scooter the electric system plays an important role in its design and development. The electronic system consists of battery, motor, motor controller and other electronic equipment. The most important thing is that electronic system does that, it gives power to the motor which helps in the operating of the scooter. The energy in the form of chemical or electric energy is been deposited in the battery, which is used by the hub motor. Thus this energy is converted to mechanical energy. A good electronic system is important to ensure driver as well as vehicles safety in case of accident. The BLDC motor is assembled to the hub of rear wheel of electric scooter.

The main Objective is to design and develop an electric scooter are as following:-

1) To reduce running cost of vehicle.
2) To reduce the emissions.
3) To overcome the draw backs of electric vehicle.
4) To increase durability and efficiency of electric scooters.

Following are the key components in Electric Scooter:-

1. Battery Charger
2. Battery
3. Motor
4. Controller
5. DC-DC Converter
6. Vehicle Computer and Electronics

- Wire Diagram for Battery charger-

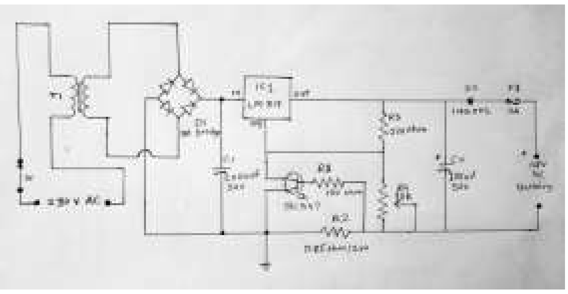

**Fig1.** Simplified Wire Diagram battery charger

- Battery Specification-

| Parameter | NiCd | NiZn | NiMH | Li-ion/Li-Po |
|---|---|---|---|---|
| Specific Energy (Wh/kg) | 40-60 | 100 | 60-120 | 100-265 |
| Energy Density (Wh/L) | 50-150 | 280 | 140-300 | 250-730 |
| Specific Power (W/kg) | 150 | >900 | 250-1000 | 250-340 |
| Charge/Discharge Efficiency (%) | 70-90 | 80 | 66 | 80-90 |
| Self-Discharge Rate (%) | 10 | 13 | 30 | 8-5 |
| Cycle Durability (cycles) | 2000 | 400-1000 | 500-1000 | 400-1200 |
| Nominal Cell Voltage (V) | 1.2 | 1.65 | 1.2 | NMC 3.6/3.7, LiFePo4 3.2 |

## 1. Performance Analysis-

- Battery Calculation-

→ Power Equation-

Power (P) = Current (I) × Voltage (V)
Hence, 1200 = 60 × Current (I)
Current (I) = **20 Amps** (theoretically)

→ Now, to run the 1200 watts motor for 1 hour,
1200× 1 hour = **1200 watt-hour**

→ The rated efficiency of 80% is for battery
Hence, 1200/0.8 = **1500 Watt-hour**

→ Now, the watt-hour of battery into Ampere hour of battery will be
P = V × I
1500 = 60 × I
**I = 25 Ampere-Hour**

Therefore, to run the 1200 watts motor for 1 hour, 60V 25AH Lithium-Ion battery is needed. If the electric scooter is running at an average speed of 25 km/hr. 60V 25AH provides 25 km mileage i.e. if you want 25 km mileage (range), 60V 25AH Lithium-Ion Battery is needed.

- Motor Calculation-

Consider the weight of the scooter 200Kg and maximum speed of 45 Km/hr, so we only consider

$$F_{total} = F_{rolling}$$

Therefore the formula for force due to rolling resistance is given by:

$$F_{rolling} = Cr \times M \times a$$

- Cr = Coefficient of rolling resistance
- M = Mass of vehicle in kg
- a = acceleration due to gravity ($m/s^2$)

Let,

- Cr = 0.01
- M = 200kg
- a = 9.81 $m/s^2$

$F_{rolling}$ = 0.01×200×9.81
**$F_{rolling}$ = 19.62N**

→ Power required overcoming the rolling resistance
P = $F_{rolling}$ x Velocity (m/s)
P = 19.62 x 45 x (1000/3600)
**P= 245.46 ~ 246 Watts**

Total Power required to overcome these resistance forces = 246 watts

Therefore, to design an electric bike of 200kg and to run at a maximum speed of 45km/hr. we need 1200 W motor.

- Damper Calculation-

The material of the spring is taken as SS Spring Wire according to ASTM A 313. This load is shared by two shock absorbers. Therefore the load on each shock absorber will be half of this value = 80.02 kg = 784.8 N

→ Modulus of Rigidity (G) = 69000 N/mm2
→ Mean Diameter of the coil ($D_m$)=

$$D_m = \frac{48+44.2}{2} = 46.25mm$$

→ Diameter of the Spring Wire (d) = 8mm
→ Maximum Outer Diameter of Spring ($D_o$) = 56mm
→ Total Number of coils ($n_t$) = 14
→ Number of Active coils (n) = 12
→ Spring Index ( C)= $\frac{Dm}{D} = \frac{46.25}{8} = 5.7$
→ Free length of the spring (Lf) = 200mm
→ Solid Length of the spring ($L_s$) = d x $n_t$ = 8 x 14 = 112mm.
→ Pitch of the coils-

$$(p) = \frac{Lf-Ls}{nt-1} + d = \frac{200-112}{13} + 8 = 14.76mm$$

→ Whal's Stress Factor-

$$(k) = \frac{4c-1}{4c-4} + \frac{.615}{c} = 1.2674$$

→ Deflection of spring under load (δ)-

$$\delta = \frac{8Wc3\ n}{Gd} = 25.57mm$$

→ Max. Shear Stress in the spring (τ)-

$$\tau = \frac{k\times8\times Do}{\pi d3} = 310.6\ MPa$$

→ Spring Stiffness (K)-

$$K = \frac{Gd4}{8Dm3\times n} = 29.7579\ N/mm$$

Therefore, the technical specification matching with the OEM damper can be opted.

- **Calculation for Swing arm-**

| | |
|---|---|
| Diameter of a front wheel | 10” |
| Diameter of a rear wheel | 10” |
| Wheelbase | 1175 mm |
| Length of a swing arm; axle to axle | 380 mm |
| Width of Brush Less DC motor | 144 mm |
| Maximum carrying mass | $m$=200 $kg$ |
| BLDC motor peak power | 2 kW |
| Maximal tilt in turning conditions | $\tau$=35° |
| Approximate location of CoG from rear axle | $b$=300$mm$ $h$=767$mm$ |
| Dynamic longitudinal coefficient of friction | $\mu_d$=0.7 |
| Static longitudinal coefficient of friction | $\mu_s$=1 |
| Motor Torque | $T$=50 $Nm$ |
| Front wheel radius | $RF$=254 $mm$ |
| Rear wheel radius | $RR$=254 $mm$ |
| Mass percentage on a rear wheel | 74.5% |
| Load on a front axle | $N_{sf}=F_{\%}\times m\times g$= 501 $N$ |
| Load on a rear axle | $N_{sr}=R_{\%}\times m\times g$=1461 $N$ |
| Driving force | $Pr=(T/R_R)$=196.85 $N$ |
| Vertical force of inertia | $Ntr=(S\times h)/p$=122.3 $N$ |
| Dynamic load on the front wheel during acceleration | $N_{acf}=N_{sf}-N_{tr}$ =378.7 $N$ |
| Dynamic load on the rear wheel during acceleration | $N_{acr}=N_{sr}+N_{tr}$=1582.3 $N$ |
| Static braking force on a front wheel | $F_f=N_{sf}\times\mu_s$=501 $N$ |
| Static braking force on a rear wheel | $Fr=N_{sr}\times\mu_s$ =1461 $N$ |
| Total static braking force | $F_B=F_f+F_r$= 1962 $N$ |
| Dynamic braking force on a front wheel | $F_{Bf}=N_{sf}+(F_B\times h/p)$ =1781 $N$ |

| | |
|---|---|
| Dynamic braking force on a rear wheel | $F_{Br}=N_{sr}-(F_B\times h/p)=181\ N$ |
| Maximum speed | $v=45\ kmh=12.5\ ms$ |
| Minimal turning radius with maximum speed | $R=v^2/(\tan\tau\times g)=22.74\ m$ |
| Centrifugal force during turning conditions | $Fctrf=(m\times v^2)/R$ $=1374.23\ N$ |

→ **G1 case:-**

The basic analysis to conduct is called as G1 test. It checks how swing arm reacts during maximum load on a rear wheel in normal G acceleration. Formula below presents how load acting on a swing arm was calculated.

$$F_{G1}=R_{\%}\times m\times g\times \mu_s+N_{tr}=1612.3N$$

- $F_{G1}$ [newton]– load on a rear axle in G1 conditions,
- $R_{\%}$ [%]– mass percentage on a rear wheel,
- $g$ [$Nkg$] – Earth's gravitational acceleration,
- $\mu s$ – static longitudinal coefficient of friction,
- $N_{tr8}$ [$N$] – vertical force of inertia

→ **Longitudinal stiffness**

Force acting on the swing arm, that needs to be considered is driving force. It's the force that "push" motorcycle forward, therefore swing arm is compressed. Presents result of analysis.

$$F_{LS}=N_{Sr}\times \mu_s=1461N$$

Where:

- $FLS$ [$N$]– maximum load in horizontal direction,
- $NSr$ [$N$] – vertical force of inertia,
- $\mu s$ – static longitudinal coefficient of friction

→ **Torsional stiffness**

Along with the longitudinal stiffness, the next most important natural direction is torsional stiffness. To check it, it is needed to establish minimum turn radius with maximum velocity. It is calculated based on tires type, coefficient of friction and CG of motorcycle with a driver. Following formula presents calculation of maximum centrifugal force. Results of analysis are presented in

$$F_{TS}=(m\times v^2)/R\times R\%=1023.8\ N$$

Where:

- $F_{TS}$ [$N$] – max centrifugal force,
- $m$ [$kg$] – motorcycle max weight,
- $v$ [$m/s$] – max velocity,
- $R$[$m$] – min radius of turn with max velocity,
- $R_{\%}$ [%]– mass percentage on a rear wheel

→ **Turning Condition:-**

In real life turning conditions, motorcycle is not only exposed on acting of centrifugal forces, but also standard gravitational ones.

$$F_{G1}=R_{\%}\times m\times 1g\times \mu_s+N_{tr}=1612.3N$$

$$F_{CTRF}=(m\times v^2)/R\times R_{\%}=1023.8N$$

$$F_{TURN}=\sqrt{(F2ctrf + F2G1}=1909.72\ N$$

Where:

- $F_{G1}$ [$N$]– load on a rear axle in G1 conditions
- $F_{ctrf}$ [$N$]– centrifugal force
- $F_{TURN}$ [$N$]– resultant force acting on swing arm in turning conditions

According to the factors considered above, one has to select the swing arm which satisfies all the technical specification.

→ **Block Diagram-**

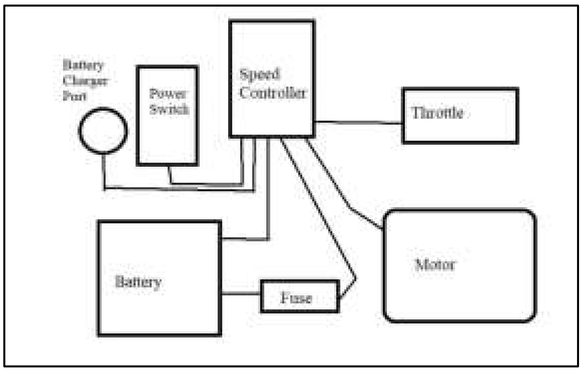


**Fig-2** Block Diagram Circuit

## 4. Conclusion:

Electric vehicles are the future of our world with the increasing consumption of non-renewable resources such as petroleum, diesel which leads us to step our way towards the renewable sources such as solar hydroelectric power and battery. There are alternative ways by which we can save energy. One of such way is electric bike; it is also the new way of transport which provides us easy way of transport to provide of any age. It is cheap source of transport and affordable to anyone. The motor used in this bike has high efficiency and the battery bank has less weight with high speed. These bikes are environmental friendly, needs less maintenance and can be also assembled to small component.

As we know the most important motto of our project was to design and assemble all the important components that are required to convert a SI 2 wheeler into an electric scooter. The abovementioned components can be used in any old moped.

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