# Design and Development of Electric Bike

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**Abstract –** *The depleting non-renewable energy sources and its hazardous impact on an environment has forced us to think out of the box and take active moves in the field of renewable energy sources. Conventional Internal Combustion Engines use the maximum share of the non-renewable energy sources and as soon as possible we need to find alternatives for the same. In this study, we have designed an Electric Bike which is completely eco-friendly and based on the electric motor concept as an alternative to the Internal Combustion Engine. The selection of batteries and motors while designing such concept totally depends on the desired output or the working load conditions. This dissertation concentrates on designing and analysing the frame of a two-wheeler, two-seater bike for an electric mobility purpose, while considering strength, safety and optimum performance of the vehicle.*

***Key Words***: Energy sources, environment, electric bike, eco-friendly, electric mobility.

## 1. INTRODUCTION

Electric motor is used as a prime mover in the electric bikes. The motion of an object is achieved by transforming the electric energy into movement. The electric bikes are equipped with rechargeable batteries and this phenomenon helps to power the bike according to individual needs.

Two important types of motors used in the electric bikes are brushed and brushless DC motors. The functionality of these kinds of bikes can be improved by introducing an electric power assist system. The alternatives available while making a choice of batteries are lithium-ion batteries, nickel-cadmium batteries, lead-acid batteries etc. The configuration of battery changes according to the voltage and capacity required for the vehicle. It is really an important task to select the appropriate rating of motor based on the load to be carried.

The bike frame is a non-standard structural component of bike that links various components of the vehicle systems and provides the vehicle rigidity and strength while operating on various road conditions. This study aims designing and analysing the frame of a two-wheeler, two-seater bike for an electric mobility purpose, where the quality of safety, strength and optimum performance of the vehicle are utmost.

### 1.1 Power Transmission

Electric vehicle is one of the best future technologies for reducing the use of fossil fuels and also to act as environmental friendly by reducing the emission of harmful gases. The electric vehicle has many components like charging module, converters, controllers, batteries, electric motor etc.

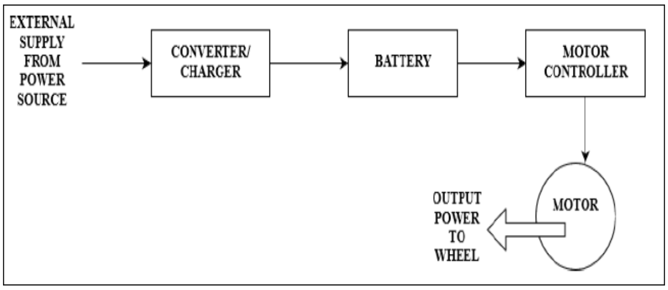


**Fig -1**: Block diagram of electrical components connection.

The power supply is obtained externally by using Power source to generate electricity or from domestic AC supply. This power is then rectified using converter and is made available to the battery through charging module.

Motor controllers are used to supply the power of batteries, which helps in controlling the input and output parameters of the motor. Drive shaft is used to transfer the mechanical power from the motor to the wheels. In this way, electric power flows through various components in an electric bike and gets converted into mechanical power. Therefore, it is clear that an electric motor determines the output characteristics of vehicle as a whole in terms of power, torque, speed, etc.

The electric motor selected for driving a bike must have the ability to provide sufficient power and torque to overcome the force due to load and other opposing forces acting on the bike. The entire Electric vehicle has one thing in common that all of them use direct electric current motors to drive the wheels. However these motors are available with the number of variation in speed, size and method of operation, the torque required from the vehicle to obtain desirable characteristics is the same. It is the torque that forms the part of force to drive the wheels and set the vehicle in motion. In simple terms the torque is defined as the turning power of the motor.

## 2. DESIGN

### 2.1 Motor Power

While deciding the power rating of motor for an electric vehicle, vehicle dynamics has to be considered like rolling resistance, aerodynamic drag or acceleration resistance force and gradient resistance.

FTotal = Fr + Fg + Fa
PTotal = Pg + Pr + Pa

Where,
FTotal = Total force
Fr = Force due to rolling resistance
Fg = Resistance due to road inclination
Fa = Resistance offered by air drag
Pg = Power required to overcome gradient resistance
Pr = Power required to overcome rolling resistance
Pa = Power required to overcome aerodynamic drag
PTotal = Total power required to overcome the resistance

In order to run the vehicle on road, motor has to overcome FTotal (i.e Total tractive force) means output of motor must be greater than PTotal. Therefore while selecting drive motors for an electric vehicle, some factors like Rolling Resistance, Grade Resistance and Acceleration Force must be taken into consideration to determine the required maximum torque.

### 2.2 Rolling Resistance

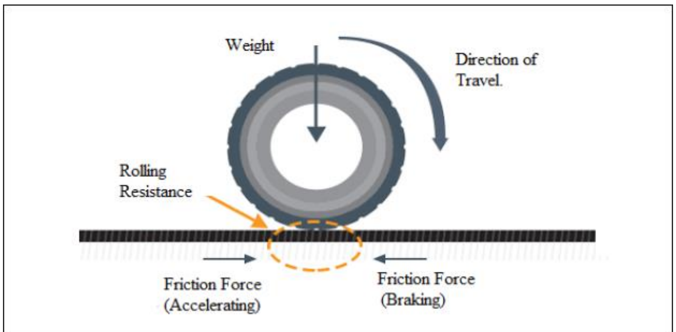


**Fig -2**: Rolling Resistance of Wheel

Fr = GVW*Crr
Pr = Fr*V

Where,
Pr = Power required to overcome rolling resistance
GVW = Gross Vehicle Weight
Crr = Co-efficient of rolling resistance

Depending on different roads conditions, the values of co-efficient of rolling resistance changes. For design consideration, the concrete road surface with fair condition is taken into account.

**Table -1:** Values of co-efficient of Rolling Resistance

| Contact Surface | Crr |
|---|---|
| Concrete(good/fair/poor) | 0.010/0.015/0.020 |
| Asphalt(good/fair/poor) | 0.012/0.017/0.022 |
| Macadam(good/fair/poor) | 0.015/0.022/0.037 |
| Snow(2 inch/4 inch) | 0.025/0.037 |
| Dirt(smooth/sandy) | 0.025/0.037 |
| Mud(firm/medium/soft) | 0.037/0.090/0.150 |
| Grass(firm/soft) | 0.055/0.075 |
| Sand(firm/soft/dune) | 0.060/0.150/0.300 |

### 2.3 Gradient Resistance

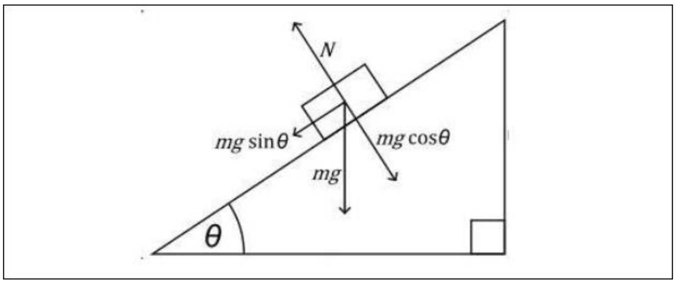


**Fig -3**: Gradient Resistance of Wheel

It is the force that pulls down when it's climbing an inclined surface. It is a form of gravitational force. If the vehicle is trading uphill at a slope of θ, as shown in figure, then the weight of the vehicle "W" has two components; One perpendicular to road surface (Wcosθ) and other along the road surface (Wsinθ).

Fg = GVW*sinθ
Pg = Fg*V

Where,
Pg = Power required to overcome Grade Resistance
θ = Inclination Angle

### 2.4 Acceleration Force

Acceleration force is the force that helps the vehicle to reach a predefined speed form rest in a specified period of time.

F = 0.5*Cd*A*ρ*V
Pa = 0.5*Cd*A*ρ*V^2

Where,
Pa = Power required to overcome aerodynamic drag
Cd = Drag co-efficient
ρ = Density of Air
V = Speed of the body relative to the fluid.

According to different shape of vehicle which is exposed in the opposite direction to air, the values of drag coefficients are; Sphere – 0.47, Half Sphere – 0.42, Cone – 0.50, Cube – 1.05, Angled Cube – 0.80, Long Cylinder – 0.82, Short Cylinder – 1.15, Streamlined Body – 0.04, Streamlined Half Body – 0.09.

In case of bike the opposing surface to air is similar as a long cylinder shape so that for design purpose 0.82 drag coefficient is considered.

## 2.5 Total Tractive Power

The total tractive power is to run the vehicle on the road is calculated by summing up all above three forces. But electric motor of such power not selected because there are some transmission losses which have to take into account. Therefore the mechanical power output (Ptractive) required to drive the vehicle is given by;

Ptractive= PTotal/ η

Where,

η = Efficiency of the transmission gear system

PTotal = Pg+Pr+Pa

Consider the efficiency of the transmission system to be 0.98 (Chain Drive).

## 2.6 Mathematical Calculations

Considering, gross vehicle weight 150 kg with rider i.e. 150 * 9.81= 1471.5 N= 1472 N Velocity of vehicle 40 kmph i.e. 40*5/18= 11.11 m/sec.

Pr = 1472*0.015*11.11 = 245.30 W

Here, Crr= 0.015 is taken from table-1 for concrete fair road conditions.
Let, the bike runs on a flat road surface, therefore, the angle θ=0°.
In this case, the power required to overcome gradient resistance is also zero.

Pg = 1472*sin(0)* 11.11= 0

Let, drag coefficient from a table 1 for long cylinder shape i.e.0.82 and area of vehicle that resists dragging force is 750 mm width and 1000 mm height.

Pa= 0.5*0.82*(0.75*1)*1.2*11.112 = 3.82 W

PTotal = PG+PR+PA

PTotal = 0+245.3+3.82 = 249.12

Consider the efficiency of the transmission system to be 0.98 (Chain Drive).

Ptractive = PTotal /η

Ptractive = 250/0.98 = 255.10 W

As per above calculations and conditions total power of motor required to run the vehicle on road is around 260 W, but considering gradient resistance which changes respect to road conditions required more than 500 W of motor power, therefore motor of 750 W is selected.

After studying the various aspects related to EV, the drafted prototype of the vehicle frame is ready and the calculations comes at the point that the motor required to run the vehicle is of 750 W with 48 V rating then continues drawing current is 15.625 A, therefore battery of 20 Ah capacity is selected.

## 2.7 Battery Calculations

Motor of 900 W, 48 V is selected. Therefore maximum drawing current will be;

P = V*I
900 = 48*I
I = 18.75 Amp = 19 Amp

Therefore, if drawing current is 19 Amp for continuous 1 hour then battery should of 26 Amp. For better lasting, battery having capacity of 26 Amp is selected. Now battery having capacity of 26 Amp easily gives backup more than 1 hour. So, final selected battery is shown in figure. In this battery pack, four batteries are taken having individual capacity of 12V and 26 Amp to get required power to drive the motor. The batteries are connected in series. So the final output of battery pack is 48V 26 Amp.

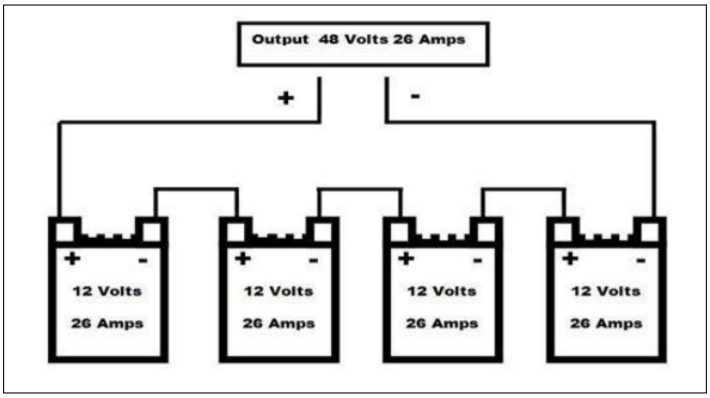


**Fig -4**: Battery Connection

## 2.8 Power Train Calculations

Motor speed at no load condition = 3000 rpm

Required speed on the road = 45 km/hr
= 45 km/hr *1000000/60
= 750000 mm/min

Radius of tire = 8 inch = 203.2 mm

Required rpm on road = 750000/203.2
= 3691 rpm

Circumference of tire = π*D
= π*16
=50.265 inch

1 mile = 63360 inch
Therefore,
Revolutions of wheel required to go for 1 mile
= 63360/50.265
=1260.52 revolutions

45km/hr = 27.962 mph
Therefore to go 27.962 mph;
= 1260.52*27.962
= 35247 revolutions/hr
= 35247/60
= 587.45 rpm (at wheel)

Now motor will spin at 3691 rpm and wheel will spin at 587.45 rpm.

Gear ratio = N motor/N wheel
=3691/587.45
=6.28

### 2.9 Selection of Chain Drive

Chain drive is a mechanism in which power is transmitted from an engine to the wheels of a vehicle or a boat's propeller by means of a moving endless chain. It is an array of links held together with each other with the help of steel pins. This type of arrangement makes a chain more enduring, long lasting and better way of transmitting rotary motion from one gear to another. Chain drive is selected from the above calculations.

In traditional method number of gears were linked together in order to transmit the required motion. This problem of large number of gears is resolved by introducing a chain drive, and the motion is transmitted with the help of two gears and a chain over a long distance.

### 2.10 Braking System

There are number of different types of braking systems available in the market. Here we are using the Drum Brakes to carry out our application.

**1. Rear Braking System**

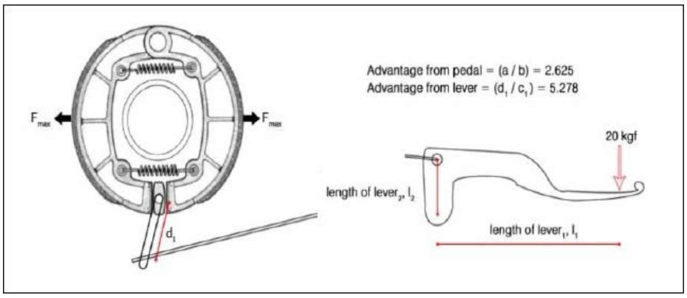


**Fig -5**: Arrangement of Rear Drum Brake

Force applied on the lever:
Flever = 20 kgf

Advantage offered by the lever:
Advlever = (a/b) =2.625

Advantage offered by the drum lever:
Advlever = (d1/c1) = 5.278

Force applied at the cam:
Fcam = Flever*Advhand lever*Advlever=494.465kgf

Coefficient of friction between brake shoe and brake drum:
μ = 0.4

Maximum force applied by the brake shoes:
Fmax =2*Fcam*μ =395.565kgf

Maximum brake torque:
Tmax =Drum Diameter*Fmax =0.13*395.565
=51.42kgf-m.

**2. Front Braking System**

Force applied on the lever:
Flever = 20 kgf

Advantage offered by the hand lever:

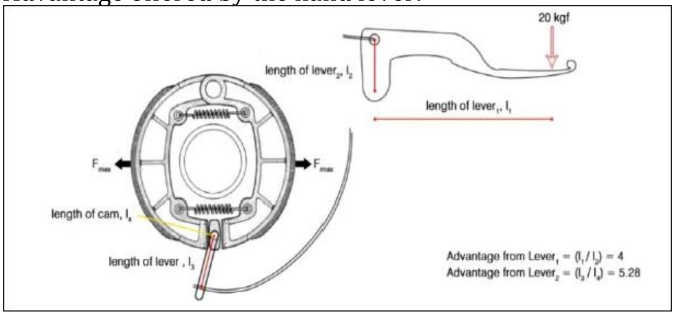


**Fig -6**: Arrangement of Front Drum Brake

Advlever1 = (l2/l1) =4

Advantage offered by the drum lever:
Advlever2 = (l3/l4) =5.278

Cable efficiency:
η = 0.8

Force applied at the cam:
Fcam=Flever*Advlever1*Advlever2 =337.792kgf

Coefficient of friction between shoe and drum:
μ = 0.4

Maximum force achieved by the brake:
Fmax = 2*Fcam*μ =270.234kgf

Maximum brake torque:
Tmax =Drum Diameter*Fmax
=0.13*270.234 =35.13kgf-m

**RESULTS:**
Maximum brake force for a rear drum brake = 395.565 kgf
Maximum brake force for a front drum brake = 270.234 kgf
Maximum brake torque for a rear drum brake = 51.42 kgf-m
Maximum brake torque for a front drum brake = 35.13 kgf-m

## 3. BIKE FRAME CAD MODEL

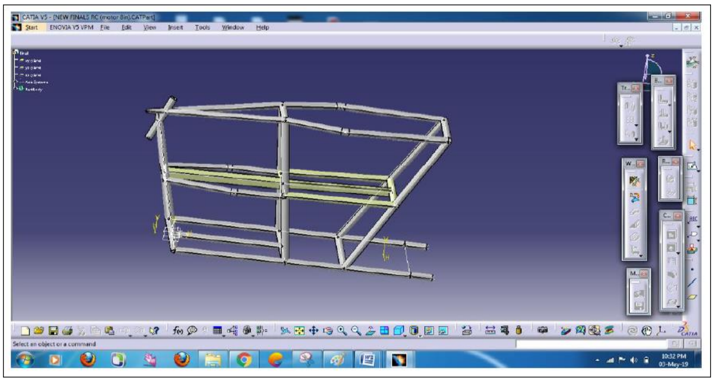

**Fig -7**: CAD Model of bike frame

The most important step in the manufacturing of electric bike is to design the frame of bike. Frame of bike is designed on CATIA software. All the dimensions are as follows:

Length = 36 inch
Width = 13 inch
Height = 21inch
Weight of bike = 150-170Kg (with rider)

## 4. ANALYSIS

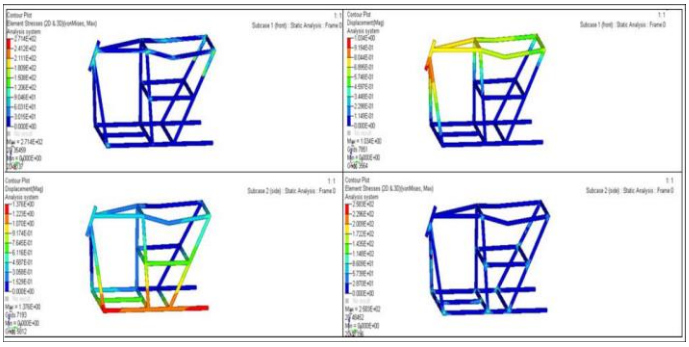

**Fig -8**: CAD Model of bike frame

### 4.1 Strength Analysis

To understand the products performance, lifecycle and possible failure modes we need to carry out the strength analysis. Mechanical loading, thermal stress, bolt tension, pressure conditions and rotational acceleration are just some of the factors that will dictate strength requirements for materials and designs.

ANSYS Mechanical ensures your products viability and safety by predicting the strength required for the loads your design will experience in service.

### 4.2 Structural Analysis

ANSYS structural analysis software enables to solve complex structural problems and make better and faster design decisions. It is used to optimize their product design and reduce the cost of actual physical testing. In the analysis of the e-bike frame, on the front side 5g force has been applied and on the sides 2g force has been applied. Analysis is done on frame with outer diameter of pipe is 1inch and 0.1mm thickness.

### 4.3 Material Selection and Specification

The key design decisions of our frame that would greatly increase safety, reliability and performance is material selection. For ensuring selection of the optimal material, extensive research and material comparison in multiple categories is carried out. Key categories for comparison were strength, availability, weight, and cost. A steel tube with bending stiffness and bending strength exceeding that of circular steel tubing with an outside diameter of 25.4mm and a wall thickness of 1.25 mm and a carbon content of 0.32% is selected.

### 4.4 Material Selection and Specification

From this matrix it is concluded that the best available material is Chromoly AISI4130. Chromoly (AISI 4130) steel is a type of low alloy steel that gets its name from combination of the words Chromium and Molybdenum – two of the major alloying elements. Chromoly steel is often used when more strength is required than mild carbon steel. Chromoly steel is actually alloy steel grade 4130.

**Table -1:** Values of co-efficient of Rolling Resistance

| MATERIAL | CHROMOLY 4130 | ASTM A252 | AISI 1018 | IS 3074 | ASTM A106B |
|---|---|---|---|---|---|
| Carbon Content (%) | 0.32 | 0.18 | 0.18 | 0.20 | 0.30 |
| Yield Strength (MPa) | 395 | 350 | 365 | 372 | 383 |
| Tensile Strength (MPa) | 560 | 455 | 450 | 473 | 466 |
| Elongation (%) | 25 | 20 | 20 | 5 | 20 |
| Cost in rupees/m | 550 | 650 | 600 | 800 | 500 |
| Availability | Easy | Medium | Easy | Difficult | Easy |

The 30 at the end of the grade number designates that it has approximately 0.30% carbon by weight. The added chromium and molybdenum help to give the steel different properties from its mild steel counterpart, AISI 1030, even though they have same percentage of carbon. The alloying elements found in AISI 4130 help to increase the strength to a level higher than that of AISI 1030 which is increased even more using proper hardening procedure. The added chromium helps to increase the steels hardenability and also the corrosion resistance; although other types of material with more corrosion resistance property are considered if the material is to be used in corrosive environment. The added molybdenum helps to increase the toughness.

Other important benefits of AISI 4130 includes the ability to be easily hardened by heat treating or work hardening and the ability to be case hardened by using a process called Carburizing. In its annealed state, AISI 4130 has good formability, machinability and weld ability.

## 5. ADVANTAGES OF USING ELECTRIC MOTORBIKES

i. Electric bike has better 0 to 60 kmph acceleration as compared to gasoline powered bike, because it develops full torque immediately and without clutch the torque is instantly available.

ii. The prices on fuels like petrol and diesel are at peak these days where the charging on batteries using available resources is possible at very minimal cost.

iii. Electric bikes and scooters need very low maintenance as compared to gasoline based bikes. In electric bikes one basically worries about the consumables for example, brake pads, tires, etc.

iv. The electric bikes are eco-friendly, fossil fuels like petrol, diesel produces harmful gases like hydrocarbons, CO2, NOx, etc. and these gases are extremely hazardous to human health as well as a reason of increasing global warming.

## 6. CONCLUSION

i. The increasing global warming is extremely hazardous to the human life existence on the earth and completely opting out of the factors that affect the environment health negatively is necessary. This paper is an attempt to find alternative power source in place of the Internal Combustion Engine and its effective application in daily life.

ii. In the design process, various calculations are done to calculate the resistance which is offered by the electric bike. The battery rating is calculated by referring different research papers. Lead acid battery of capacity 48V 26A is selected.

iii. CAD Model of the frame is made on CATIA V5 software where the analysis is carried out in ANSYS software. Considering all the calculations and parameters, the Bike is designed to run at a speed of 45kmph.

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