# DESIGN OF A RELIABLE AND PERFORMANCE FOCUSED ELECTRIC MOTORCYCLE

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**Abstract** - *Considering the emissions caused by road transport, electric vehicles are being considered as the future or personal and commercial transport. We are already witnessing the adaptation of electric vehicles considering the cost of fossil fuels rising as the days pass. Many major countries are considering banning the sales of combustion vehicles as early as 2025; hence, the adaptation of EVs is inevitable.*

***Key Words***: EV, bike, sustainable transportation, renewable energy.

## 1. INTRODUCTION

The drawback of the internal combustion engine (ICE) is pollution. Hence, the requirement to find out an appropriate substitute has notably increased in recent years. Hybrid electric vehicles (HEVs) and Electric vehicles (EVs) are the substitute if the ICE since they are capable of operating with lower impact on the environment. However, EV's have did not gain popularity because of a single problem, the energy-storage capacity of electrical batteries is much less than that of fossil fuels, so it cannot be used for a longer drive. However, in recent years there has been development in the technology of the EVs, which solves the above problem.

In this paper, we have designed an electric bike, which will have high efficiency and will overcome the problem of performance decline on low battery power. Analysis has also been performed on various components of the bike such as chassis, shock absorber.

**Components of E-bike:**

1. Chassis: It is the backbone of electric motorbike and is made up of M.S. along with some additional lightweight components. The chassis is designed to sustain the weight of the person driving the unit, the weight of load to be conveyed and to hold the accessories like battery.

2. Swing arm: A swing arm or swinging arm, originally known as a swing fork or pivoted fork, is the main component of the rear suspension of most modern motorbikes and ATVs. It is used to hold the rear axle firmly while pivoting vertically, to allow the suspension to absorb bumps in the road.

3. Steering: It is used to turn the bike as per our choice.

4. Suspension system: The suspension serves a dual purpose of contributing to the vehicle's handling and braking, and providing safety and comfort by keeping the vehicle's passengers comfortably isolated from road noise, bumps and vibrations. The front suspension is of the type telescopic fork.

5. Brushless DC (BLDC) Motor: A brushless DC electric motor, also known as an electronically commutated motor (ECM or EC motor) or synchronous DC motor, is a synchronous motor using a direct current (DC) electric power supply The wheel hub motor (also called wheel motor, wheel hub drive, hub motor or in-wheel motor) is an electric motor that is incorporated into the hub of a wheel and drives it directly. The specification of motor used are 4000W 72V DC hub motor and the weight of the motor is 26kg.

6. Wheels:

7. Motor controller: A motor controller is a device that controls possibly every action of the motor A 72-volt 150 amperes motor controller is used it is designed such as it controls every operation, which includes speed control of the motor and Braking system. A Motor controller is the brain of the motor. A motor controller is a combination of power electronics and embedded micro-computing elements, which make the conversion of energy stored in batteries of an electric vehicle to generate motion.

8. Brakes: Brakes are used to stop a vehicle from moving. In an electric motorcycle, brakes play an important role as the electric motorcycle moves at high speed so in case of any unknown scenario brakes should be of a good type to stop the electric motorcycle and avoid accidents.

9. Battery: The battery is the powerhouse of an electric motorcycle so to make a Motorcycle design that has a very good range a rechargeable battery should be used as it can be recharged and used.

**Battery management system:**

When a person buys an EV, the top concern is the safety and reliability of the power system in a vehicle. The most important question is whether they will run out of battery power on the road. These issues refer to the estimation and prediction of SOC, SOH, and SOL of the EV battery. Thus, an accurate quantification of the battery status has become one of the most critical tasks for BMSs. In this section, the latest methodologies for battery state estimation and prediction are reviewed.

1. State of charge (SOC)

SOC is critical, but it cannot be measured with the current onboard sensing technologies. The ratio of the currently available capacity to the maximum capacity can be expressed as SOC, which is calculated by Equation (1):

$$SOC = 1 - \frac{\int idt}{Cn} \quad \text{... (1)}$$

Where *i* is the current and *Cn* is the maximum capacity that the battery can hold.

2. State of health (SOH)

SOH reflects the health condition of the battery and its ability to deliver specific performance compared to a new battery. A new feature was called sample Entropy (SampEn) was proposed which served as an indicator of SOH.

$$\text{SampEn}(m, r, N) = -In\left[\frac{A^m(r)}{B^m(r)}\right]$$

where N is the total number of data points, m is the length of sequences to be compared, r is the tolerance parameters, $B^m(r)$ is the mean value of two similar signal segments that are composed from input vectors with m points, and $A^m(r)$ is similar to $B^m(r)$ and will match form+1 points.

3. State of life (SOL)

SOL is also known as remaining useful life (RUL) of a battery

A proposed battery management system:

Battery management system has two parts Hardware and Software. Their further classification is shown in picture below:

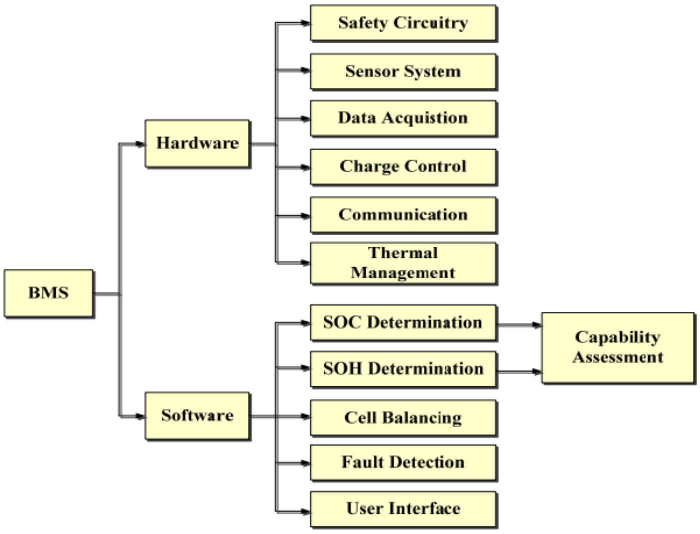


**Figure 1 BMS**

1. Hardware:

Safety circuitry is used in BMS for a long time but due to the advance development of BMS there has been addition of alarms and controls to prevent overcharge, over-discharge, and overheating of the battery.

The sensor system has different sensors to monitor and measure battery parameters including cell voltage, battery temperature and battery current.

Data acquisition (DAQ) and data storage are important parts in the BMS to analyze and build a database for system modeling.

The charge control system is an important sub-system of the BMS, which is responsible for the charge discharge protocol.

Communication in BMS mostly happens through a Controlled Area Network (CAN bus). With the development of smart batteries, with help of micro-controller the communication between the battery charging time and user can be developed.

Thermal management is critical because temperature differences have an impact on cell imbalance, reliability and performance.

2. Software:

The determination of SOC and SOH is integrated into a capability assessment, which represents the life status of the battery and sets the operating limits according to the algorithms used.

The main objective of cell balancing is to maximize the battery performance without overcharging of over-discharging of the battery.

Fault detection is required to provide battery fault warning and to indicate out-of-tolerance conditions.

The user interface is used to display the essential information such as the remaining range, abnormal alarming and replacement suggestions of the battery to the users.

Challenges of BMS and possible solutions

The challenges that the vehicle BMSs are facing are given below

1. Capacity Estimation under Varying Loads and Environmental Temperatures
2. Estimation of maximum capacity

The capacity of the battery is calculated by Capacity =

$\int Idt$

Longer the integration time, the higher the battery capacity will be.

3. Communication mechanisms

The communication in the BMS happened thought CAN bus; the battery transmits data such as current condition, usage history SOC indication through SMBus. It is difficult to make such mechanisms and different applications. Wireless technology helps to gather the external environment data, like humidity, temperature, and able to communicate between the battery and the charger.

4. Assessment of Battery Health

Assessment of battery health is very important. The battery technology in EV is not yet well developed so there is a specific need for building a large database. The increase in cell resistance, decrease in actual capacity and number of charge and discharge cycles are the factors that can be used to evaluate the health status of the battery.

5. Battery disposal and Recycling

As the number of EVs used are increasing the disposal of the batteries have become a significant issue. The best solution to this is recycling the batteries. Tesla reuses their 60% of the battery's materials, which is a grate strategy.

## 2. SPECIFICATIONS

*A.* Electrical connections

HV (High voltage)

1. Motor
2. Controller
3. Battery

LV (Low voltage)

1. Light
2. Speedometer

*B. Motor* - QS 273 17inch E-Scooter Hub Motor(40H) 4000W V3 Type

**Figure 2 Hub motor (1)**

**Figure 3 Hub motor (2)**

**Figure 4 Hub motor (3)**

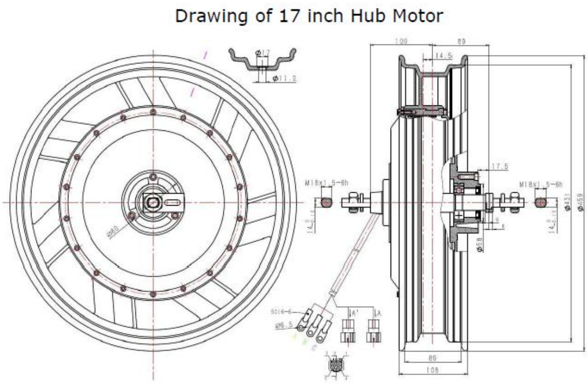


**Figure 5 Hub motor schematic**

1. Motor Type: BLDC Hub Motor with Permanent Magnets
2. Motor design: Double axle out with 17inch Aluminium rim
3. Rim size:3.5"x17
4. Matching tire: 130/70-17
5. Magnet Height: 40MM
6. Number of Pole Pairs: 16 pairs
7. Rated Power: 3000W
8. Max Power:4600W Peak 6000W
9. Rated Voltage: 48V,60V,72V
10. Speed: 45-100KPH
11. Max No-load RPM:515-1220rpm
12. Max Torque: 200N.M
13. Max Efficiency: 90%
14. Continuous current:50A
15. Max current:100A
16. Brake Type: Disc brake
17. Rear Fork width for installation: 200mm
18. Cross Section of Phase wire: 16 mm$^2$/3 phase
19. Hall sensor phasing angle: 120 degree
20. Temperature Sensor: KTY84-130
21. Working Temperature: 70 degrees, Peak 120 degree
22. Waterproof Grade: IP66
23. W. / G.W. : 24kgs / 25kgs
24. Package Size: 58*58*40 cm

*C. For driver Sine Wave Brushless Motor Controller ND72490*

Model Number: ND72490

Max. Bus Current: 180A

Max. Phase Current: 660A

Working Voltage: 52V-90V

Size: 189mm*121mm*63.5mm

Weight: 2Kgs

Support Regen and Programmable by USB cable or Bluetooth

Circuit diagram:

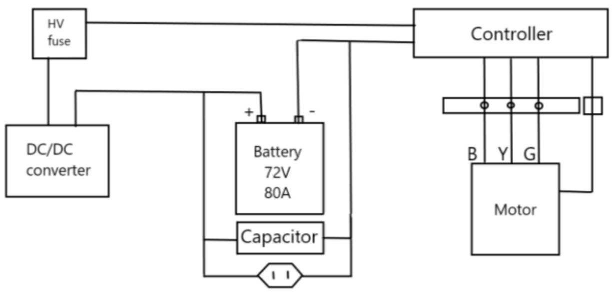


**Figure 6 Main circuit diagram**

**Figure 7 Motor Controller (1)**

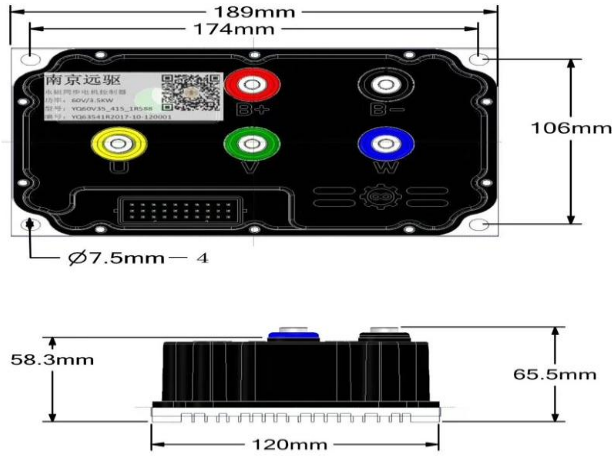


**Figure 8 Motor Controller (2)**

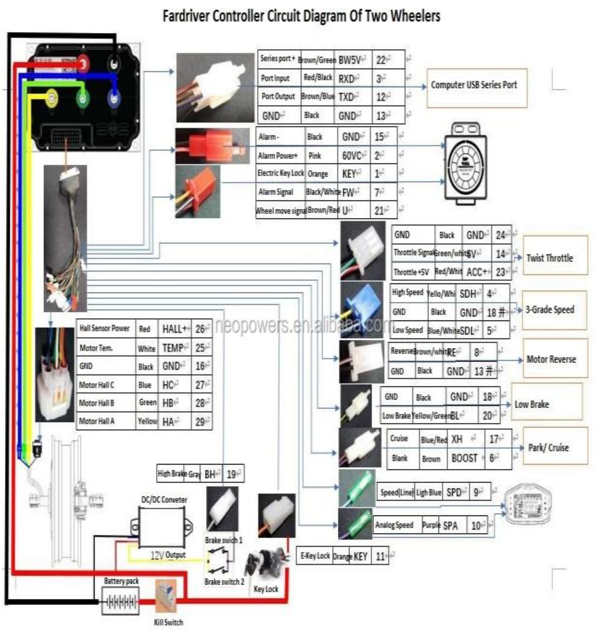


**Figure 9 Motor Controller & connections**

*D. Battery – 72V Li-ion*

*E. HV contractor (MCB/fuse)*

Applied on positive end in between battery to the controller (100A to 150A)

*F. DC-DC converter*

15A to 30A for accessories such as headlights, taillights, etc.

*G. Connections*

Phase connector

Battery connector

Copper wire

6mm to 8mm copper wire (HV)

2mm to 6mm copper wire (LV)

*H.* Charger – 15A,72V (AC to DC)

The charger is connected parallel to the battery

*I.* Accessories

Blinkers

Taillight

Headlight

ODO, multi, speedometer

*J. Handling/Braking/Shock up*

Rack angle – 24°

Braking – Disc brake (Front + Rear)

Shock up – Telescopic (Front), Mono shock (Rear)

*K. Disc Brake Assembly Kits*

Rear Hub Motor Disc Brake Kits

Brake disc diameter: 220mm

Brake disc thickness: 3.5mm


**Figure 10 Disc brake assembly kit**

*L. Twist Throttle*

Hall Twist Throttle

Inner hole diameter 2.3mm

Throttle bar length = 15 cm

Wires definition:

Thin Red wire +5V

Black wire GND

White wire Hall Signal


**Figure 11 Twist throttle**

*M. Chassis* - 2*1(inch) Rectangular casing Seamless (Mild Steel)

*N. Body* - 2mm sheet metal

*O. Front* - (ktm rc 200 wheel suspension, brake caliper, master cylinder, triple clamp, bearing. bearing housing)

*P.* Temp sensor - KTY84-130

Work temp = 70° C to 120° C (100° C - cut off)

IP 66 Rated, weight = 25 kg

*Q.* **Super capacitor**

Super capacitor connected parallel to battery pack and controller. Main use of capacity pack is to maintain instantaneous voltage and as capacitor are easy and fast to charge compared to battery pack. Regenerative energy can be used to charge capacitors rather than battery, which gives us more effective regenerative uses.

Bus bar

1. Farad capacitor – 2.7V, 500F

   36 * 60 mm super capacitor

2. 3.5 mm, 2.7V, 500 F

   Balance board, super capacitor, stabilization protection

## 3. CALCULATIONS

*A. Motor RPM/Torque*

3. Weight

   Battery = 40 kg

   Controller = 2 kg

   Motor = 25 kg

   Material = 15 kg

   Other weight = 15 kg

   Kerb weight = 97 kg

   20 kg payload, 75 kg avg. person weight

   **Total weight = 192 kg (200 kg)**

4. Tire size (rear) = 17 inch

   For 80 km/hr

   Tire rim diam. = 17 inch * 25.4 = 432 mm

   Rubber tire height = 130 * 0.7 = 91 mm

   Total tire diam. = 432 + (91+91)

   = 614 mm

   **Total tire radius = 307 mm**

5. Tire circumference = 2*Π*r

   = 2*3.14*307

   = 1927.96 mm (1928 mm)

   **Linear travel of tire in 1 revolution = 1928 mm (2 m for calculations)**

   For 80 km/hr

   80 km/hr = 22.22 m/s

   RPM required for this speed = speed/linear travel = 22.22/2 = 11.11 RPS

   = (22.22*60)/2 = 666.6 RPM

   **Therefore, for 80 km/hr speed, the minimum RPM required from the motor must be ≥ 667 RPM**

*Bike frontage resistance (Standard data)*

Bike frontage resistance = Bike width * total height

Bike width = 715 mm

Bike height = Rider + Bike

= 1115 + 600

**= 1715 mm**

Bike frontage resistance = 715 * 1715

$= 1.22 * 10^6 \, mm^2$

**$= 1.2 \, m^2$**

*B. Total forces acting on the bike*

1. Total resistance = Rolling resistance + Grad. Resistance + Drag + Inertia

   a. Rolling force ($F_r$) = f(mg) ... *(Due to tire on road)*

   f = Coefficient of friction (tarmac/ standard road)

   m = total mass

   g = acceleration due to gravity = 9.8 $m/s^2$

   $F_r = 0.02 * (200 * 9.8)$

   **$= 39.2 \, kg.m/s^2 = 39.2 \, N$**

   b. Drag force/ Aerodynamic force ($F_d$)

   Drag force = $(½)*\rho*c*v^2*A$

   ρ = density of the air

   c = coeff. of drag

   v = velocity

   A = Frontal area

   $F_d = (½) * 1.2 * 0.8 * (22.2)^2$

   **= 289.87 N**

   c. Acceleration force/ inertia force ($F_a$)

   $F_a = ma$

   $a = \Delta v/t$

   $= ((40 - 0)*100)*(15 * 3600) = 0.74 \, m/s^2$

   $F_a = 200 * 0.74 \, m/s^2$

   **= 148 N (100 N for calculation)**

   d. Gradient force ($F_g$)

   Acts when driving on an inclined surface

   $F_g = mg\cos\theta$

   for θ = 5°

   = 200 * 9.8 * 0.23

(Hypothetical)

Total forces = $F_r + F_d + F_a + F_g$

= 39.2 + 282.87 + 148 + 176.58

**= 646.65 N**

Power (P) = + $F_{(Total)} * V$

**= 646.65 * 22.22 = 14355.63 W**

*C. Motor selection (Torque)*

P = 2ΠNT/60

N = RPM

T = Torque

14355 = 2 * Π * 666.6 * T/60

**T = 205N-m (Required torque)**

(Practical)

Total forces = $F_r + F_g + F_a$

= 39.2 + 282.87 + 100 = 422.07 N

Power (P) = F * V = 422.07 *22.2 = 9378.3 W

9378.3 = P = 2ΠNT/60

= 2 * Π * 666.6 * T/60

**T = 134.4 N-m**

**Minimum torque required for 80 km/hr from motor ≥ 135 N-m**

*D. Motor selected*

P = 4000 W, (4600 max) (6000 W Peak)

V = 72 V

Max RPM (No load) = 512-1200 RPM

Max torque = 200 N/m

Max efficiency = 90 %

17-inch aluminium rim 3.5" * 17"

Tire - 130/70 - 17"

Rear fork width = 200 mm

*E. Controller (ND 72490)*

Max current = 180 A (USB Programmable)

Work voltage = 72 volts, weight = 2kg

Dimensions = 189 * 121 * 63.5 mm

*F. Battery calculations*

1. Battery Power

   Power (P) = Voltage (V) * Current (I)

   4000 = 72 * I

   **I = 55.55 A (Theoretical)**

2. The capacity of the battery

   For 4000 W motor to run for 1 hour

   **4000 W * 1 hr = 4000 Wh**

3. Efficiency = 80%

   4000 Wh / 0.8 = 5000 Wh

   Watt-hour to Amp hour

   Current needed = 55.55 A

   **η = 5000/72 = 69.43 Ah**

*G. Battery pack cell calculation*

1 cell Li-ion

Voltage = 3.7 V, current = 2000 mAh = 2Ah

Power (P) = V * I = 3.7 * 2 = 7.4 Wh

For 72 volt, 80 Ah = 72/3.7 = 19.4 ≈ 20

**80Ah/2Ah = 40 rows**

**Total number of cells = 20 * 40 = 800**

*H.* No. of super capacitor = 72/2.7

= 26.66 = 28 (approx.)

**4. Design**

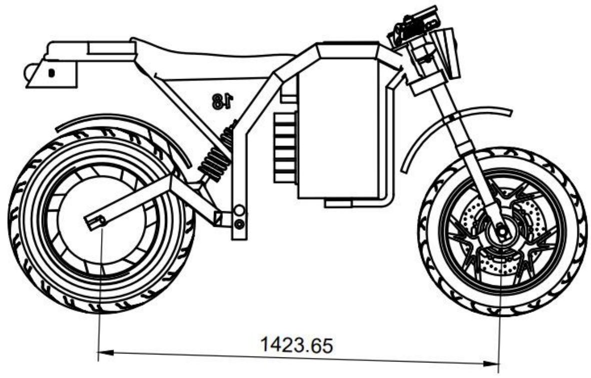


**Figure 12 Bike design - RHSV**

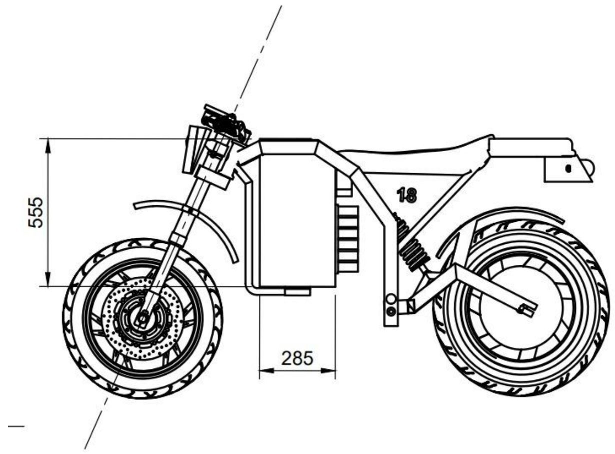


**Figure 13 Bike design - LHSV**

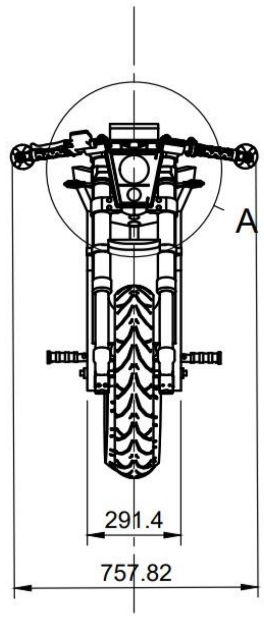


**Figure 14 Bike design - Front**

**Figure 15 Bike design render (1)**

**Figure 16 Bike design render (2)**

**Figure 17 Bike design render (3)**

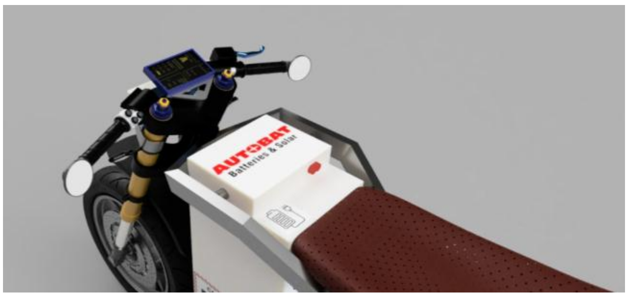

**Figure 18 Bike design render (4)**

## 5. ANALYSIS

1. **Chassis**
   a. Stress

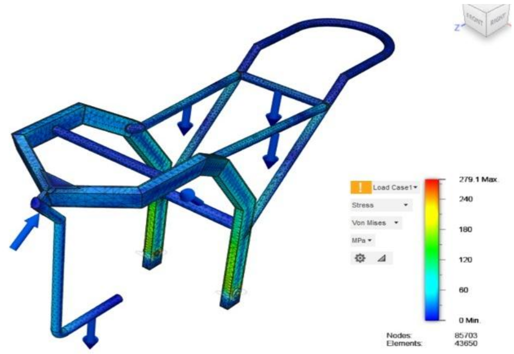

**Figure 19 Chassis stress analysis**

   b. Maximum deformation

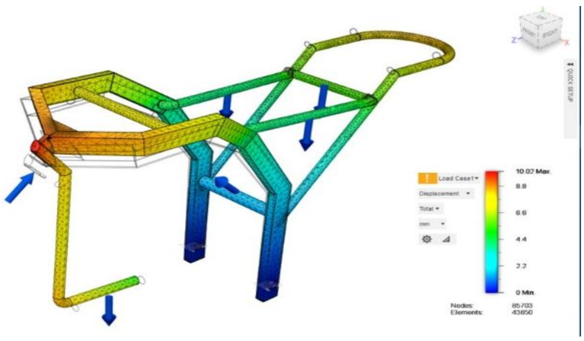

**Figure 20 Chassis deformation analysis**

### ⊟ Study Properties

| | |
|---|---|
| Study Type | Static Stress |
| Last Modification Date | 2021-12-30, 11:37:57 |

**Table 1**

### ⊟ Mesh

| | |
|---|---|
| Average Element Size (% of model size) | |
| Solids | 10 |
| Scale Mesh Size Per Part | No |
| Average Element Size (absolute value) | - |
| Element Order | Parabolic |
| Create Curved Mesh Elements | Yes |
| Max. Turn Angle on Curves (Deg.) | 60 |
| Max. Adjacent Mesh Size Ratio | 1.5 |
| Max. Aspect Ratio | 10 |
| Minimum Element Size (% of average size) | 20 |

**Table 2**

### ⊟ Materials

| Component | Material | Safety Factor |
|---|---|---|
| Body4 | Steel AISI 1018 118 QT | Yield Strength |

### ⊟ Steel AISI 1018 118 QT

| | |
|---|---|
| Density | 7.87E-06 kg / mm^3 |
| Young's Modulus | 207000 MPa |
| Poisson's Ratio | 0.33 |
| Yield Strength | 290 MPa |
| Ultimate Tensile Strength | 496 MPa |
| Thermal Conductivity | 0.0519 W / (mm C) |
| Thermal Expansion Coefficient | 1.15E-05 / C |
| Specific Heat | 486 J / (kg C) |

**Table 3**

### ⊟ Mesh

| Type | Nodes | Elements |
|---|---|---|
| Solids | 85703 | 43650 |

**Table 4**

1. **Swing arm**
   a. Stress

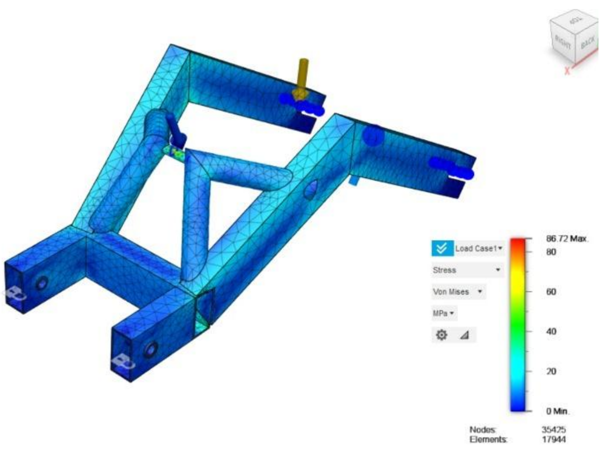


**Figure 21 Swing arm stress analysis**

b. Maximum deformation

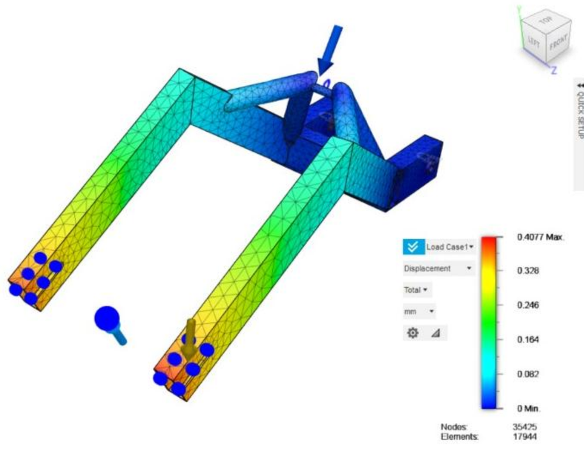


**Figure 22 Swing arm deformation analysis**

### ⊟ Study Properties

| | |
|---|---|
| Study Type | Static Stress |
| Last Modification Date | 2021-12-24, 00:09:20 |

**Table 5**

### ⊟ Mesh

| | |
|---|---|
| Average Element Size (% of model size) | |
| Solids | 10 |
| Scale Mesh Size Per Part | No |
| Average Element Size (absolute value) | - |
| Element Order | Parabolic |
| Create Curved Mesh Elements | Yes |
| Max. Turn Angle on Curves (Deg.) | 60 |
| Max. Adjacent Mesh Size Ratio | 1.5 |
| Max. Aspect Ratio | 10 |
| Minimum Element Size (% of average size) | 20 |

**Table 6**

### ⊟ Materials

| Component | Material | Safety Factor |
|---|---|---|
| Body16 | Steel AISI 4130 366 QT | Yield Strength |
| Body14 | Steel AISI 4130 366 QT | Yield Strength |

### ⊟ Steel AISI 4130 366 QT

| | |
|---|---|
| Density | 7.85E-06 kg / mm^3 |
| Young's Modulus | 207000 MPa |
| Poisson's Ratio | 0.33 |
| Yield Strength | 1357 MPa |
| Ultimate Tensile Strength | 1426 MPa |
| Thermal Conductivity | 0.0427 W / (mm C) |
| Thermal Expansion Coefficient | 1.12E-05 / C |
| Specific Heat | 477 J / (kg C) |

**Table 7**

### ⊟ Mesh

| Type | Nodes | Elements |
|---|---|---|
| Solids | 35425 | 17944 |

**Table 8**

**2. Suspension**

### ⊟ Stress

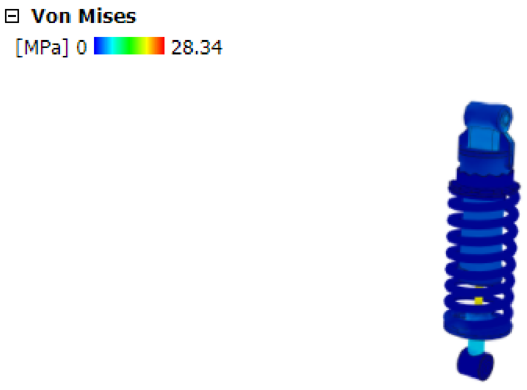


**Figure 23 Suspension stress analysis**

### ⊟ Study Properties

| | |
|---|---|
| Study Type | Static Stress |
| Last Modification Date | 2022-01-09, 11:01:26 |

**Table 9**

### ⊟ Mesh

| | |
|---|---|
| Average Element Size (% of model size) | |
| Solids | 10 |
| Scale Mesh Size Per Part | No |
| Average Element Size (absolute value) | - |
| Element Order | Parabolic |
| Create Curved Mesh Elements | No |
| Max. Turn Angle on Curves (Deg.) | 60 |
| Max. Adjacent Mesh Size Ratio | 1.5 |
| Max. Aspect Ratio | 10 |
| Minimum Element Size (% of average size) | 20 |

**Table 10**

### ⊟ Materials

| Component | Material | Safety Factor |
|---|---|---|
| bottom plate v2:1/Body8 | Steel | Yield Strength |
| bottom plate v2:1/Body7 | Steel | Yield Strength |
| bottom plate v2:1/Body4 | Steel | Yield Strength |
| bottom plate v2:1/Body1 | Steel | Yield Strength |
| bottom plate v2:1/Component1:1 | Steel | Yield Strength |
| bottom plate v2:1/Component2:1 | Stainless Steel AISI 302 | Yield Strength |
| cylinder v1:1/Body1 | Steel | Yield Strength |
| cylinder v1:1/Body2 | Steel | Yield Strength |
| cylinder v1:1/Body3 | Steel | Yield Strength |
| cylinder v1:1/Body4 | Steel | Yield Strength |
| cylinder v1:1/Component1:1 | Steel | Yield Strength |
| bush v1:1 | Steel | Yield Strength |
| spring head v1:1/Body6 | Steel | Yield Strength |
| spring head v1:1/Body7 | Steel | Yield Strength |
| spring head v1:1/Body8 | Steel | Yield Strength |
| spring head v1:1/Body9 | Steel | Yield Strength |

**Table 11**

### ⊟ Steel

| | |
|---|---|
| Density | 7.85E-06 kg / mm^3 |
| Young's Modulus | 210000 MPa |
| Poisson's Ratio | 0.3 |
| Yield Strength | 207 MPa |
| Ultimate Tensile Strength | 345 MPa |
| Thermal Conductivity | 0.056 W / (mm C) |
| Thermal Expansion Coefficient | 1.2E-05 / C |
| Specific Heat | 480 J / (kg C) |

**Table 12**

### ⊟ Stainless Steel AISI 302

| | |
|---|---|
| Density | 8E-06 kg / mm^3 |
| Young's Modulus | 204773 MPa |
| Poisson's Ratio | 0.29 |
| Yield Strength | 386.1 MPa |
| Ultimate Tensile Strength | 715.7 MPa |
| Thermal Conductivity | 0.0162 W / (mm C) |
| Thermal Expansion Coefficient | 1.172E-05 / C |
| Specific Heat | 500 J / (kg C) |

**Table 13**

### ⊟ Mesh

| Type | Nodes | Elements |
|---|---|---|
| Solids | 56855 | 29621 |

**Table 14**

## 6. COST

| SR | Component | Rate |
|---|---|---|
| 1 | Batteries | 1,00,000 |
| 2 | Motor | 45,000 |
| 3 | Chassis Material | 5,000 |
| 4 | Disk brake | 10,000 |
| 5 | Suspension | 10,000 |
| 6 | Extra acc. | 12,000 |
| 7 | Controller | 20,000 |

**Table 15**

Total = Rs. 2,02,000 /-

## 7. CONCLUSIONS

Electric Vehicles differ from traditional petrol or diesel powered vehicles as they operate on electricity, which can be obtained from renewable and non – renewable energy sources unlike the latter ones, which can only be powered, by non – renewable energy sources. Hence, we can drastically reduce the carbon footprints by using renewable energy sources for electricity generation such as solar, wind, water, etc. Here we have designed electric vehicle that is battery operated. In this project, our main motive was to design a battery charging circuit and Controller circuit for battery based electric vehicle. In this semester, we have successfully completed the simulation and designing part of our Final year project.

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