Design and Fabrication of Power Train and Suspension for Electric bike

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Abstract: **-** In the present context, fuel plays an important role but due to the global warming and also increase in the price of the fuel which is not affordable for normal people which leads to pollution. Thus in order to overcome an alternate approach, is use of other sources of energy one such is electrical energy. The main aim of this paper is to use Electric energy as the primary source instead of fuels. This work compromises with design, fabrication of power train and rear suspension. It also highlights on the design aspects of the bike with its specification. Lithium ion batteries are used to power the motor to achieve maximum range and to obtain optimum speed of the bike. A rear suspension model has been modeled and the part analysis of rear suspension is done using solid works by considering all various dynamic boundary conditions. The swing arm with mono shock is used as rear suspension by considering the dominance properties. In order to evaluate the performance of the electric bike a various experiments are conducted such as acceleration, economical power consumption, maximum speed which are the end results of the work and optimum results are obtained[1.1].

Keywords- Power train, Li ion battery, Rear suspension

I. INTRODUCTON

The development of internal combustion engine vehicles and especially automobiles is one of the greatest achievements of modern technology. Auto mobiles have made great contribution to the growth of modern society by satisfying many of the needs for mobility in everyday life Motor cycle design varies greatly to suit a range of different purposes like long distance travel, commuting, cruising, sport including racing and off road riding. In 1894 Hildebrand &Wolf Muller became the first series production motorcycle, and the first to be called a motorcycle. But when we go back to history the first internal combustion, petroleum fueled motorcycle was the Daimler Reitwagen. It was designed and built by German inventors Gottlieb Daimler and Wilhelm Maybach in Bad Cannstatt Germany in 1885 [1].

However, the large number of automobiles in use around the world has caused and continues to cause serious problems for environment and human life. Air pollution, global warming, as motor cycle's exhaust emissions contains oxides of nitrogen (NOx), carbon monoxide, unburned hydrocarbons, sulphur oxides carbon dioxide particulate matter. Due to emission of such gases makes a greater impact on living beings which causes serious health problems.

1.1 Formation of pollutants

The relative proportions of the major pollutants in exhaust emission depends mainly on the specific organization and parameters of the ignition and combustion process in the Internal Combustion Engine (ICE) fuels are usually matched to engines although the full utilization of the advantages of some alternative fuels requires modification of the engine or the development of a new type of engine. In the recent decades, the research and development activities related to transportation have emphasized the development of high efficiency clean and safe transportation. Electric vehicles (EV), hybrid electric vehicles and fuel cell vehicles have been typically proposed to the place of convectional vehicles. The first EV's were introduced early as 1838 or 52 years before internal combustion engine vehicles entered the market. Despite recent growing interest, EVs have remained a relatively small market until today. However the global share of EVs is expected to increase significantly, driven by substantial battery technology improvements and a variety of policies that are accelerating the development of the electric vehicle market. Overall the market has grown now.

1.2 Types of Electric drive trains

BEVs – Battery electric vehicles
PHEVs – Plug in hybrid electric vehicles (Hybrid Vehicles)

1.3 Effect and advantages

In India usage of bikes are more but development of E-Bikes are less. It is essential in order drive towards E-Bikes into the market as there will be depletion of natural resources that most automobiles are running on. Of course, electric motorcycles don't belch any smoke and don't use limited non-renewable fuel. The production methods are improving, batteries are becoming recyclable and there are many sources of renewable power including charging of your bike off your home's solar power.

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1.4 Current cost

Even though EV has no engine, which implies significant cost savings over a period of time, substantial costs arises from the large battery packs currently required.

1.5 Power and torque

- Most importantly for riders, electric motor cycles are fast.
- EVs hold the Pikes Peak hill climb record for both cars and bikes.
- An electric motor has instant 100% torque which means rapid acceleration.

1.6 Low maintenance

- Electric bikes don't have air filters, oil, spark plugs, timing belts and some don't have a clutch and gear box
- So there is very little to check, replace or maintain, expect tires, brake pads and brake hydraulic fluids. Even the brake pad last longer as the electric motor can do lot of braking.

II. PHASES OF DESIGNING POWER TRAIN

This section elaborates different stages involved in designing the power train for electric bike

2.1 Design of battery pack

Most crucial part in designing a battery pack is selecting its type, Lithium ion cells were commonly used for designing a battery pack of electric bike because of its dominance properties with other types. Lithium ion cells includes characteristics like long cycle life, high energy density, more safe, low self-discharge rate, good charging speed, low internal resistance, high discharge rate, cost effective among others[1][2]. Lithium ion cells have low maintenance cost than other chemistries. These cells can be substituted for high loads because of its flat discharge rate. The specifications of cell used is provided in table 1.1 given below

Table 1.1: cell specifications

Brand	Samsung
Model	INR18650-13Q
Capacity	1300mah rated
Voltage	3.6V nominal
Charging	4.2V maximum ,910mA standard,4A maximum
Dimension	65*18 (mm)

- Series connection: The positive terminal of one cell is connected to negative of another cell then connection will be in series and the voltage will get multiplied
- Parallel connection: The positive terminal of one cell is connected to positive of another cell then the connection will be in parallel, in this connection both discharge and storage capacity (AH) will get multiplied

The battery is designed by connecting combination of lithium cells in series and parallel using nickel strips as shown in figure 1 and 2 to obtain required voltage and AH (amp hour). As connecting cells in series increases voltage whereas parallel increases capacity.

Figure 1: Battery pack


Figure 2: Nickel strip

Thus to ensure the enhancement of the capacity, the 13 no's of cells are connected in parallel the battery pack is capable of storing 15.6 AH and can deliver maximum discharge of 150A. The battery pack has a potential of 58.2 volts by connecting 14 no's cells in series. The nickel strips are welded to cells by using custom built spot welder. Since it is dangerous to carry high potential pack in bike, the battery is designed for 58.8 volts.

2.2 Connecting battery management system (BMS) to battery pack

The major issue with electric vehicle is the battery; the battery must be frequently monitored in order to optimize the performances and its life. The battery monitoring is the main goal of battery management system (BMS) which must be carefully selected. The BMS has to report its data in order to perform simulation through user interface based on real time scenarios and data. The smart BMS uses artificial intelligence and formal methods to determine the state of charge (SOC) precisely [3] .SOC can be used to know how well the battery is functioning with respect to normal and fail condition. The Accurate estimation of state of charge (soc) prevents battery damage by avoiding over charge and over discharge. The battery aging should be conditioned in suitable manner through controlling discharge and charge profile [4]. Proposing smart BMS for multi cell battery in order to improve the effectiveness of battery monitoring and current sensing, modeling the battery aging process and to provide self-healing ability for the circuit to compensate performance variations.

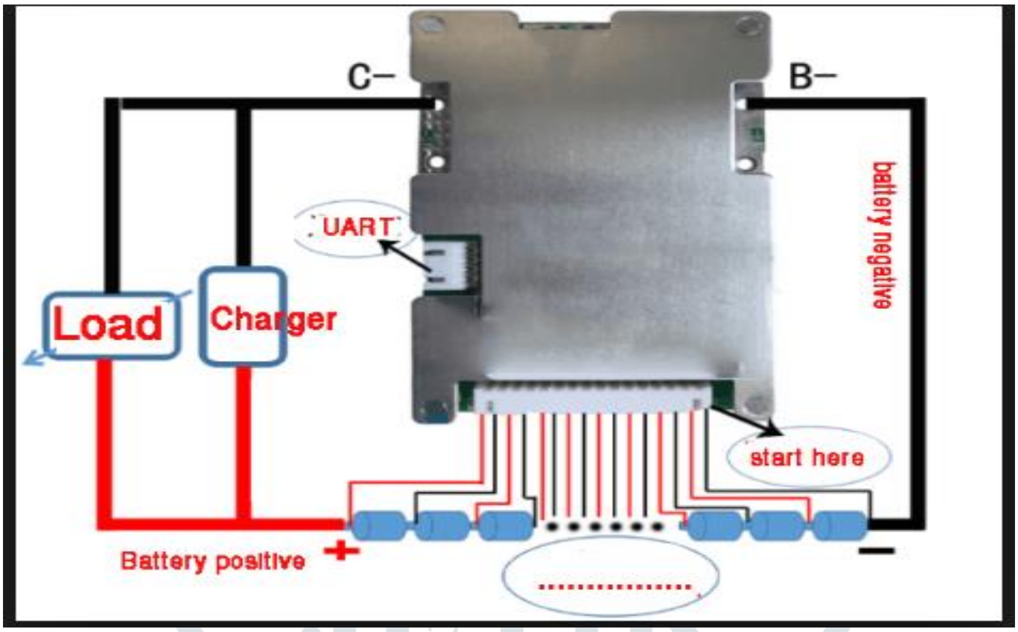

Figure 3: Circuit diagram of BMS connections

There are mainly two sets of wires one set is of thick gauge wires which mainly meant for charging and discharging, the others are thin wires used as balance wires. The wiring schematic is shown in figure 3, there are two main terminals B- and C- among which B- is connected to negative terminal of the first series of battery pack. The C- terminal is drawn from negative terminal of load and charger .The load is drawn from the C- and positive terminal of the battery pack, C- terminal also be used as negative terminal for charging, positive terminal can directly be connected to positive terminal of battery pack for charging. The no of balance wires in BMS will be same as no of series of cells in the battery pack and are named from B0 to B14 the battery pack has 13 no's cells stacked in parallel and 14 stacks of these kind are connected in series which are named from 1 to 14.The first B0 balance wire will be connected to negative terminal of first series set and the preceding balance wire B1 is connected to the positive terminal of next series set similarly all even numbered balance wires are connected to negative terminal of odd numbered series stack of cells and all odd numbered balance wires are connected to positive terminal of even series stack of cells. The communication with the BMS can be done through UART port either by connecting Bluetooth module or through CAN cable in order to change the parameters such as balancing, maximum charge current, peak discharge current, cutoff voltage through user interface software shown in figure 4.

Figure 4: User interface software for BMS

2.3 Brushless dc motor (BLDC)

BLDC motors as shown in figure 5 provide more efficiency and better performance compared to other direct current (DC) motors .Brushless DC motors are DC motors which are commutated electronically instead of mechanical brushes as in case of regular dc motor[5][6].

To commutate a BLDC motor, the position of the rotor with respect to the stator is required which is obtained either by back EMF or through rotary sensors such as HALL sensors, rotary magnetic encoders [7].

BLDC motors are most often used in electric vehicle because of its advantages such as

- Power to size and weight ratio.
- High efficiency.

- Low frictional loss.
- Low maintenance.
- High reliability

Figure 5: BLDC motor

2.3.1 Motor specification

The following are the motor specification as listed below,

- Voltage = 48volts
- Speed = 4000rpm
- Power = 4.5KW = 6hp
- Peak power = 18hp
- Continuous torque = 14.3Nm
- Peak torque = 42.93Nm

2.4 BLDC controller

BLDC motor has to be operated or controlled electronically through a controller as shown in figure 6.
BLDC motor has three phase windings, which are energized individually based on rotor position, the motor consist of three Hall sensors placed circumferentially at each phase winding, these hall sensors sense the position of rotor and energizes the preceding winding. The period of energization will be short when the motor speed is low and vice versa.
By using programmable controller many parameters can be calibrated such as

- Max speed of motor
- Minimum and maximum cut off voltage of the motor
- Throttle type (hall active or potentiometer)
- Throttle sensitivity
- Cruise
- Change direction

Figure 6: BLDC controller

2.5 Controller programming.

A 4 pin connector (SM-4A) to RS232 figure 7 port is provided to the controller in order to communicate with host computer for calibration and configuration.
The controller has to be programmed for required set of values such as

- Low voltage: A low voltage value is set so that any voltage below this value is not accepted by the controller so as to protect the battery.
- Over voltage: Maximum voltage value is set beyond which controller will not operate so as to protect battery and controller.
- Identification angle: A procedure is followed to make the controller to identify the positions of the Hall Effect sensor in the motor.
- TPS type: (1) Potentiometer type: 0.5K to 5K, (2) Hall active type.
- Boost: If boost mode is enabled, controller will output maximum power for a while.

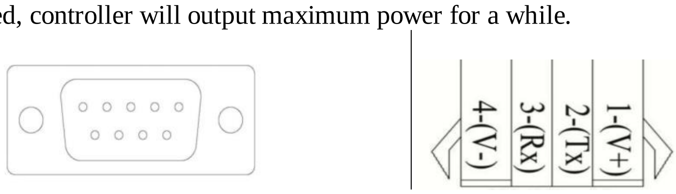

Figure 7: RS232 Interface on 4pin connector to RS232 converter

2.6 Charger

The lithium ion cell that has been used can be recharged whit a continuous supply of max direct current of 4amps. There are two major units in charging system

- DC power supply unit figure 8. It has input rated as 200 – 240 volts and AC of frequency 50 – 60Hz which can output maximum power of 350W at voltage of 24volts. In this case 230W is used at 24volts, which is supplied To the second unit of charger system buck converter.
- Buck converter as shown in figure 9 is used to charge the battery of 58V, where it needs a supply with voltage equal to 58V or more than the specified. The buck converter is set to step up the voltage from 24V to 58V with output power of 232W. Thus DC of 4amps is delivered to the battery at 58 volts.

Figure 8: DC power supply

Figure 9: Buck converter

III. REAR SUSPENSION

Usage of motorcycle has been enhanced from day to day with all the individuals. The preferable riding speed is controlled the road conditions and traffic. The roads are smooth and have uneven surfaces which results in poor ride quality and reduce the riders comfort. To overcome this conditions the mono shock suspension is used. It is the type of rear suspension system which is opted by many engineers because of its advantages. It is used because it has good ride comfort and longer rear wheel travel and this helps he agility and handling of the bike. Mono shock rear suspension assures the traction between the vehicle tyre and the road which results in good stability and ride comfort of the vehicle. The vibration is maximized to ensure the comfort of the rider and also results in good vehicle handling which in general leads to enhanced safety [9][10].

3.1 Modeling and Analysis of Rear Suspension

The rear suspension model was created by using 3D CAD package- solid works as shown in the figure 10. Further in order study the behavior of the model an analysis of rear suspension is carried out using the solid works software. By considering the maximum load of 150kg at Suspension mounting. The maximum stress of 9.308 X 10^7 N/m^2 obtained which is less than the yield stress as shown in Figure 10b.The analysis of swing arm for stain is also shown in figure 10aand the displacement is shown in figure 12. The minimum factor of safety obtained is 6.7 which is shown in figure 13

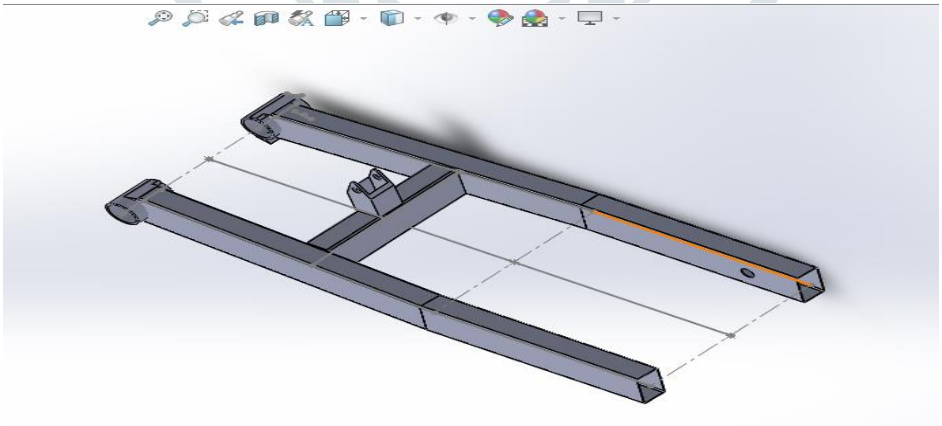

Figure 10: Rear suspension Model

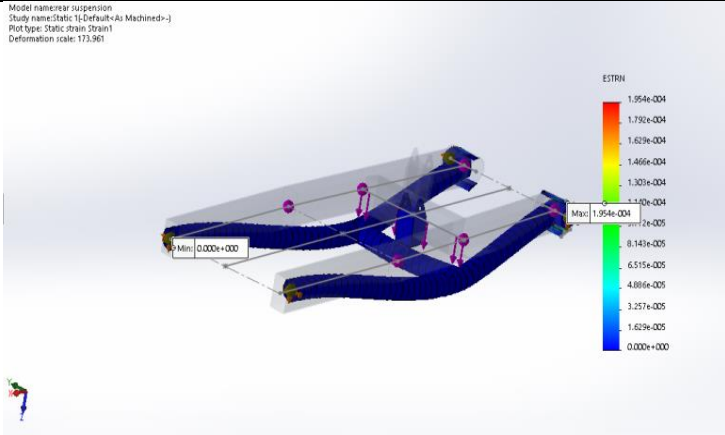

Figure 10a: strain analysis using solid works

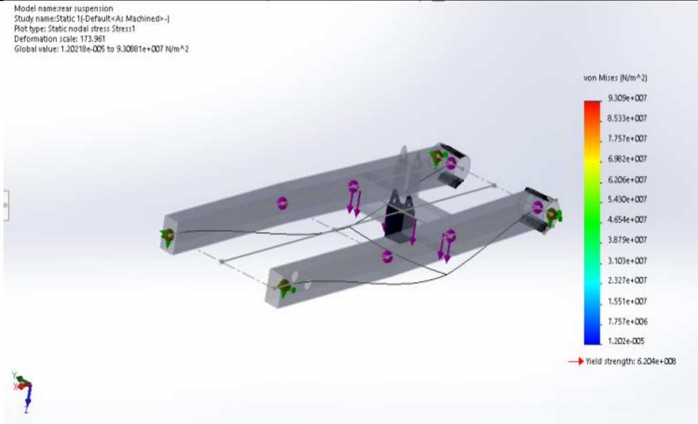

Figure 10b: stress analysis using solid works

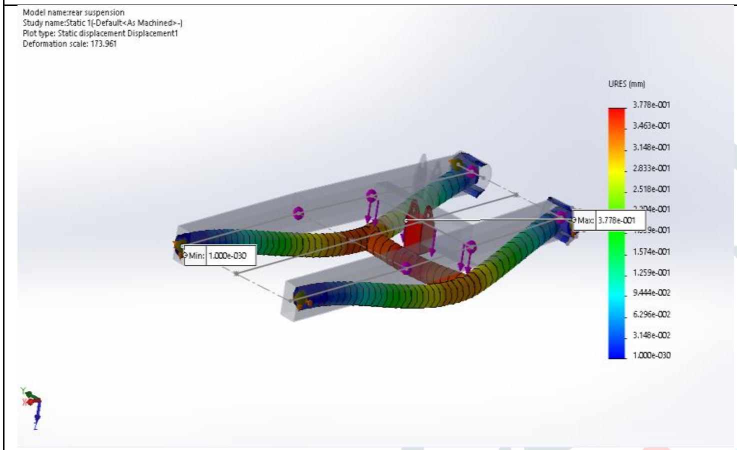

Figure 10c: Displacement analysis using solid works

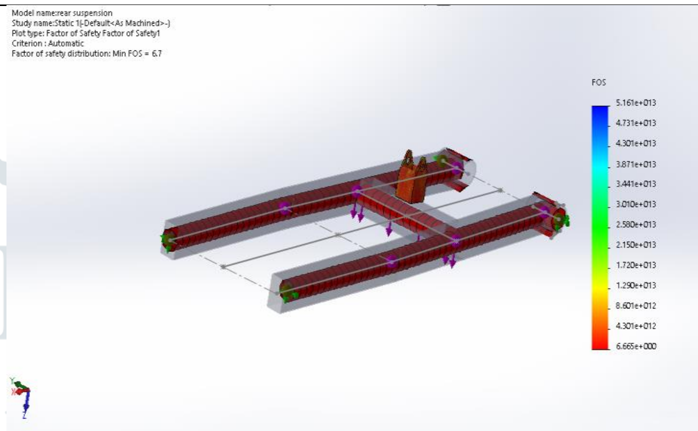

Figure 10d: Factor of safety

3.2 Electric Bike Model

After assembling all the components of bike as shown in Figure below.

Figure 10e: Electric Bike Model

V RESULTS AND DISCUSSION

4.1 Test Results of Power Train

The different practical experiments are conducted for the power train

- The Maximum current drawn from the battery is 24amps under no load at 4000rpm whereas the maximum current drawn under the load is 120amps.
- Maximum speed of the bike when the power train is tested is **80kmph**.
- The charging time of the battery pack when it is connected to 5amp charger is 1 hour (+/- 5minutes).

4.1.1 Specification Sheet

Table 4.1: Bike Specification sheet

Sl no	Particulars		Sl no	Particulars	
	Motor			**Controller**	
1	Type	BLDC	1	Model	KLS7212MC
2	Power (nominal)	6hp	2	Max current	180amps
3	Power (peak)	18hp	3	Voltage	24-72V
4	Torque (continuous)	14.3Nm		**Power system**	
5	Torque (peak)	43.93Nm	1	Power pack	Lithium ion cells
6	Speed	4000rpm	2	Maximum Discharge	150amps
7	Cooling	Air cooling	3	Charge time	1 hour(+/-15min)
	Suspension				
1	Front	Telescopic with anti friction brush			
2	Rear	Nitrox monoshock absorber			

4.1 DISCUSSION

With the depletion of fossil fuels it is necessary to move towards a new alternative mode of transportation which is electric vehicle that uses electric energy from the batteries to drive the vehicles. This energy produced is very efficient when compared to the existing IC Engines. Electric bike is cheaper and affordable to everyone. The most important feature of electric bike is cost efficient unlike the fossil fuels for IC engines are expensive but EV's distance per charge travelled is more and very cheap. Electric bike is ecofriendly and noiseless. As the operating cost per kilometer is very less and with the help of solar panel it can lessen up more. Since it has fewer components the maintenance cost is less. So keeping all this parameters in mind we have developed a model which reflects all this required parameters.

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Link

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