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A Retrofit Approach Towards Development of Geared Battery Powered Motor Bike

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Abstract: *With rapid economic expansion and industrialization, there is a pressing demand for quick and cost-effective transportation, therefore the number of motor vehicles that run on fossil fuels and non-renewable energy sources is skyrocketing every year. A number of technologies are being developed to help alleviate this dilemma, one of which is electric automobiles (EV). [1-8] As a good effect of electric motor propulsion systems, EV delivers zero emission concepts. In this context, zero-emission concepts can be applied not only to a built-in EV, but also to the conversion of a fossil-fueled vehicle to an electric one. In light of the financial constraints and the variety of new vehicle options, vehicle conversion becomes a viable investment option in line with the vehicle's utility purpose [3]. The performance requirements for electric vehicle conversions, like those for EVs, are based on a few goals: trip distance, speed, and cost. [8] The battery capacity necessary for an electric vehicle conversion based on daily trip mileage can be calculated. The range distance from fully charged to low charge EV batteries can be predicted by dividing the battery capacity by the average energy consumption per kilometer. [8] The speed target is determined by the electric motor's power. When more speed is required, the electric motor must produce more power. The voltage and current specifications required are influenced by the electric motor's power. As a result, the battery specifications are affected. Instead of reducing the battery maximum current, increasing the battery voltage can enhance the electric motor power. The cost of converting to an electric vehicle is one of the issues. The cost target is a set of parameters that emerge in addition to the technical constraints. The cost target can have an impact on mileage and speed optimization .. The cost effectiveness has an impact on determining the performance requirements for EV conversions based on trip distance and speed. The battery accounts for between 20 to 50 percent of the total cost of an EV conversion. It is dependent on the type of battery used. When evaluating the cost of an EV conversion, it is preferable to begin with determining the battery and then the requisite powertrain components. [8] This bike's key features include increased range, faster charging times, and better build quality, as well as intelligent motor and battery performance control, a Master controller that communicates with a smart display that displays the battery charge status, and a Master controller that communicates with a smart display that displays the battery charge status. [2] The four-speed transmission has been retained to ensure that the battery pack is not overloaded, resulting in smooth acceleration and a pleasant biking experience.*

Key Words: 1. electric vehicle, 2. battery pack, 3. gear box, 4. motor, 5. cost optimization, 6. performance

I. Introduction

We live in a period when ever-evolving technology require quick improvisation and adaptation. Fossil fuel-based transportation infrastructure has caused serious and harmful environmental damage in recent decades, prompting enormous endeavours and interests in the field of electric mobility. We don't have to rely on a single energy source to power electric vehicles; instead, we can use a combination of renewable and conventional energy sources such as tidal energy, solar energy, wind energy, nuclear energy, and various fossil fuels. The vehicle's carbon footprint or greenhouse effect is primarily determined by the fuel and technologies used to generate electricity. Batteries, flywheels, super capacitors, and other components are available to store electricity on board for electric vehicles. [9]

An electric vehicle (EV), also referred to as an electric drive vehicle, uses one or more electric motors or traction motors for propulsion. Three main types of electric vehicles exist, those that are directly powered from an external power station, those that are powered by stored electricity originally from an external power source, and those that are powered by an on-board electrical generator, such as an internal combustion engine (a hybrid electric vehicle) or a hydrogen fuel cell. Electric vehicles include electric vehicles, electric trains, electric lorries, electric airplanes, electric boats, electric motorcycles and scooters and electric spacecraft. Proposals exist for electric tanks, diesel submarines operating on battery power are, for the duration of the battery run, electric submarines, and some of the lighter UAVs are electrically-powered. Also, EVs bring with them various convenience and mobility related advantages such as kinetic energy recovery by the means of regenerative braking, instant plug-in charging, very low noise levels, smooth and sophisticated driving experience to name a few. It is high time to revolutionize the transportation means we rely on today and proceed towards a safer future through a prudent approach. [4].

Electric vehicles originally appeared in the mid-nineteenth century, when electricity was one of the most popular ways for motor vehicle propulsion, offering a level of comfort and ease of operation that gasoline vehicles could not match. Although the internal combustion engine (ICE) is the most common form of propulsion for automobiles, electric power is still widely used in other vehicle types, such as trains and small vehicles of all types.

Electric vehicles operate quietly and smoothly, resulting in lower noise and vibration levels than internal combustion engines. While this is a desired feature, it has also raised concerns that pedestrians who are blind, elderly, or very young are at risk due to the absence of the customary sounds of an oncoming car. To address this issue, automakers and individual companies are working on systems that emit warning sounds when electric vehicles are moving slowly, up to the point where normal motion and rotation noises (road, suspension, electric motor, etc.) become audible.

On a purely fuel to motive energy conversion basis, electric vehicles can be more efficient than conventional vehicles since electric motors are more efficient at low speeds than internal combustion engines, and they do not require any power when coasting or at rest. The single seated electric two-wheeler has become increasingly important as the proportion of two-wheeler owners has increased, with 80 percent of vehicles being utilized by a single person. The project's goal is to adapt the transmission system to create a single-seat electric two-wheeler.

1.1 Problem Statement-

Development of a gearbox-based powertrain solution in a retrofit Electric bike drivetrain using a custom lithium-ion battery pack.

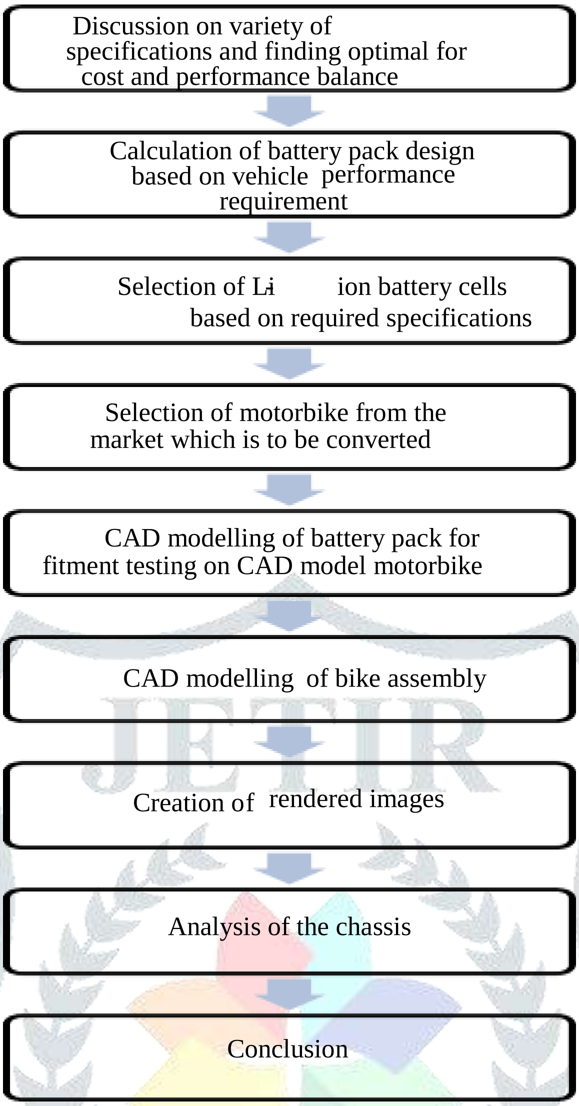
1.2 Objectives-

1. To provide a gearbox-based solution for an electrical drive train so as to use a lower powered motor and make it suitable for a wide range of driving conditions.
2. To select cells and its configuration to design a battery pack according to vehicle specifications.
3. To devise a low-cost alternative to mass-produced electric bikes.
4. To estimate the battery pack cost based on battery type and driving cycle.

1.3 Scope

1. To improve the performance of the system by utilization of higher specification batteries and electric motors.
2. Modification of chassis and suspension to fulfill special purpose requirements.

1.4 Methodology-



2. LITERATURE REVIEW-

1. Prof Sunarto Kaleb et al. [2014] had published a paper titled "Electric vehicle conversion based on distance, time and cost requirements". In that paper authors had given various parameters to do EV conversion based on performance requirements. Also, they have mentioned that when financing is constrained then the combination of distance, speed and optimum efficiency should be established. They suggested that to get a longer distance using the same voltage system, battery capacity should be enlarged. They mentioned that the battery cost reaches approximately 20-50% of EV conversion cost. Hence it is better to start with battery choice then the required drive component afterwards

2.Helena Wang [2015] converted a bicycle to an e-bike. Battery pack design is very well explained also various constraints regarding the project are taken vehicle of like cost, time, etc. Use of old materials from previous projects is done to cut the cost. Due to charger availability and cost, the battery pack is split into two packs in series. Used cells were used in the project by segregating them on the basis of measured voltage.

3.E. Fernandez, et.al.[1] has done research on simulation of two control techniques for a drive system in electric motorcycles. The controls proposed are field oriented control (FOC) and direct torque control (DTC). The analysis consists of comparing the two controls and analyzing the advantages and disadvantages of each technique. The aim is validating the best technique that provides greater efficiency, ease of implementation and most cost effective for a future implementation in a prototype electric motorcycle. The paper contributes to the implementation of means of transportation powered with electricity for student mobility in the city of Cuenca Ecuador and reducing problems of environment pollution and traffic saturation.

3.HISTORY

Robert Anderson, who invented the first crude electric vehicle, built the first electric vehicle (EV) in Scotland between 1832 and 1839, the exact year is unknown. America did not pay attention to the electric vehicle until 1895, after A. L. Ryker built an electric tricycle and William Morrison built a six-passenger waggon. The Electric Phaeton, which was more than an electrified horseless vehicle and surrey, was built by Wood in 1902. "The Phaeton had an 18-mile range, a top speed of 14 mph, and a $2,000 price tag" [1].

The decline in use and production of the electric vehicle occurred in the 1920s. Causes of the decline in production include: a better road system, reduced price of gasoline by the discovery of the Texas crude oil, invention of the electric starter, and the mass production of the internal combustion engine vehicles. By 1935, electric vehicles completely disappeared. In the 1960s and 1970s electric vehicles reappeared because internal combustion vehicles were creating an unhealthy environment for the people in America at that time. In 2006, a new start- up company emerged in Silicon Valley, calling themselves Tesla Motors, with their initial vehicle, a fully electric model Tesla Roadster. Due to Tesla's great success, the electrically powered vehicles inspired other major automakers, so that in 2010 Chevrolet presented its hybrid model Volans Nissan it's all electric vehicle, the Leaf. In 2013, BMW introduced their fully electric vehicle i3 and hybrid i8. The mainstream trend of EVs in the latest years happens to be the plug-in hybrid technology, installed in every major vehicle producer's model.

3.1 worldwide electricity and fuel prices:

Since the prices of both electricity and fossil fuels differ tremendously within continents, countries or even regions, the impact on the final expenditure dedicated to the fuel costs of any vehicle owner differs. Therefore, the local prices of both kWh and a liter of gas or diesel, as the more traditional vehicles fuels, should be considered.

3.2 Advantages and challenges per Electric Vehicle

Advantages:

1. Fuel can be harnessed from any source of electricity, which is available in most homes and businesses.
2. It reduces hydro vehicle bon and vehicle Bon monoxide, responsible for many environmental problems, by 98%.
3. Also reduces pollution.
4. Does not produce emissions. Important in urban cities, where cleaner air is much needed.
5. Less complexity in construction and so maintenance

Disadvantages:

1. Limited in the distance that can be driven before the complete failure of the battery.
2. Accessories, such as air conditioning and radios drain the battery.
3. Heavier vehicle due to the electric motors, batteries, chargers, and controllers
4. Low range and speed
5. More expensive because of the cost of the parts.
   Shortage of electricity supply in metro cities

4.Barriers and Challenges for Electric Vehicle:

4.1 Range and batteries-

The major barrier for buying any EV is the range of a single charge of the vehicle, which is much lower than for any fully tanked conventional automobile. The vast majority of the EV market nowadays, are only able to travel from 80 to 160 km on a single charge (with the Tesla, however, up to 500km, but becoming very pricey). (Boxwell, 2014) This could be considered sufficient as a daily range for most of the population; however, it is still incomparable with the range of any combustion engine vehicle. Those normally achieve 500km on a single tank, without being limited by the charging station network and being able to refill their tank at any gas station. For any regularly long-distance travelling driver, the limited range might present a problem. Continuing the talk about the range of EVs, it markedly decreases while driving on the highway at speeds higher than 130km/h, at which the vehicle needs more power[4].

4.2 Charging-

When someone owns an electric vehicle, one of their most fundamental needs is to be able to charge it quickly in order to alleviate their concerns. When travelling lesser distances around town, such as to work, the grocery store, or school, the typical vehicle range is usually sufficient for one day. The majority of electric vehicle owners (95 percent) charge their vehicles' batteries at night when they are not using them. 2014 (Boxwell) Regardless, not everyone in the population has the luxury of parking in a garage and simply plugging their car in. Many individuals park their cars on the street, and they'd be lucky to have a public charging station within walking distance of their home. Erjavec (2012, Erjavec, The next issue arises when the trip exceeds the vehicle's single charge range. In this case, the customers are forced to rely on the charging points' network. Although the number of charging stations is increasing, it is still comparable with the convenience of the gas stations and their geographical location.

density. The charging time is another issue, which might be solved with the so- called rapid chargers, adding to the vehicle's range within less than an hour. However, their occurrence is rather rare today. (Erjavec,2012)

4.3 Purchase price-

Finally, there is the question of whether the purchase price of any electric vehicle is generally speaking much higher than any other conventional market product from a given class and quality segment. The main reason for electric vehicles being so expensive is mainly their battery price, where we face now-a-days the price of 350 USD per 1 kWh of its capacity. (Wesoff, 2016) Speaking of the purchase price of any EV, let us observe it through the example of a fully battery electric Chevrolet Bolt, where the battery capacity is 60 kWh and its selling price is around 37.495 USD in the US. Given the above-mentioned price of 1 kWh, we face a battery price of 21.000 USD, which is more than half of the final selling price. (Edelstein, 2017) This fact makes it difficult for the automakers to satisfy their profit margin, while trying to offer an affordable vehicle and that is why the electric vehicles are more expensive than competing conventional vehicles.

5. DESIGN

5.1 Bike chassis for retrofitting-

The lack of clarity regarding vehicle scrappage policy has left many enthusiasts in a fix with regards to the survival of their prized possession. Also, many of the vehicles are still considered heirloom and passed down from generation to generation. In a country as big and populated as ours, these vehicles hold not only monetary but also emotional value.

With the impending sword of doom hanging in the air, threatening to take away all these old vehicles, it is necessary to find a solution which allows us to renew the registration of these vehicles and keep them running in one form or another for years to come. Retrofitting an electric drivetrain is one such option to ensure the survival of these vehicles.

5.2 Selection of Vehicle-

According to reports by business standard, there are about 51 Lacs light motor vehicles (LMV) which are older than 20 years currently plying on the road. A large part of this is contributed by two wheelers. Targeting a vehicle from this segment allows us to benefit.

There are many vehicles which can fall under this category, right from the humble Bajaj MSO to the high-powered Yamaha RD350.While selecting a vehicle to design the powertrain for its necessary vehicle. The first filter removes the RD350 and we are left with JAWA CL-II, RX100 and Rajdoot 175.

The RX100 owners already have a dependable and reliable vehicle hence a convincing shift is not possible. It already provides the demonic acceleration and pulls like a locomotive.

Rajdoot 175 lacks the desirability quotient, being more of an economical or commuter vehicle of its time and hence is not preferred as a classic vehicle by most enthusiasts.

The Jawa CL-II seems to be the perfect fit with its production spanning from early 1970s right up to late 1990s, a large number were produced and can still be seen plying on the road in the various forms as the JAVA classic, CL-II, Yezdi - CLII, Yezdi Oil King, etc.

The java also was never really famous for its reliability due to its crude construction methods and overheating issue if not maintained well paired with this a low fuel economy of the 2-stroke engine provides us with a convincing proposition to ask the owners to shift to electric drive trains.

5.3 Selected Motorbike-

A Chassis CAD model was made and further analyzed.[6]

Fig5. Actual Motorbike

- Chassis type = Frame
- Length = 2000 mm
- Height = 1100 mm
- Width = 750 mm
- Kerb Weight = 141 kg
- Wheel Base = 1350 mm

- Ground Clearance = 150 +/-5 mm
- Front wheel spindle max. load = 47 kg
- Rear wheel spindle max. load = 197 kg

Fig. 5.2 Rendered model of

Fig 5.3 CAD model of the

The CAD model of the selected bike rolling chassis was created and power train component like battery pack, gearbox, motor, etc. were added.

5.4 Power Calculation-

Calculations for Required Power: - [

Rolling Resistance-

$F_{rolling}$ = Crr x M x g

Crr = coefficient of rolling resistance = 0.004

M = mass of vehicle (loaded) in kg

= 140 (vehicle) + (2 x weight of average Indian person)

= 140 + (2 x 70)

= 280 kg

$F_{rolling}$ = 0.004 x 280 x 9.81 = 10.9872 N

2. Gradient Resistance-

F_{grad} = M x g x sin Ɵ

If we consider a gradient of 10°, Ɵ = 10°

F_{grad} = 280 x 9.81 x sin (10°) = 476.9768 N

3. **Aerodynamic drag-**

$F_{air} = 0.5 \times Cd \times Af \times \rho \times V^2$

Where,

C_d = Drag coefficient = 0.5

A_f = Frontal Area (m^2) = 0.66 m^2

ρ = Density of air (kg/m^3) = 1.1644 kg/m^2

v = velocity (m/s) = 22.22

$F_{air} = 0.5 \times 0.5 \times 0.66 \times 1.1644 \times 22.22 = 94.86$ N

4. Total tractive force-

Ftotal = Frolling + Fgrad + Fair

= 10.9872 + 476.768 + 94.86
= 582.82 N

5.Total Torque(T)

T= F_{total} × wheel radius
= 582.82 x 0.269

= 156.7796 Nm

6. Power required for Acceleration on inclined-

P = F_{total} x 22.22 x (10/36)
= 582.82 x 22.22 x (10/36)

= 3597 W = 3.597 KW

5.5 Calculation for required power-

We consider cruising conditions to sustain 80 kmph on a normal gradient.

In this, F_{roll} and F_{air} remain the same.

$F_{grad} = M \times g \times \sin(\alpha)$

α = gradient of a normal road = 2% or 1.15 ^{o}

$F_{grad} = 280 \times 9.81 \times \sin(1.15^o)$

= 55.128 N

Ftotal = Froll + Fgrad + Fair

= 10.9872 + 55.128 + 94.86

= 160.9752 N

T = Ftotal x wheel radius

= 160.9752 x 0.269

= 43.3023 Nm

Power = F_{total} x 22.22 x (10/36)
= 993.574

= 0.993 KW

Hence, our motor of 1 KW is sufficient to satisfy our cruising criteria of 80 kmph.

Now considering a single speed drive the same application would require a motor of high power of 3.597 KW. It would also not satisfy the requirement of high torque at low speed and more power at high speed due to inherent limitations posed by a single speed (single reduction drive).

Our project centered around application of gearbox allows us to satisfy the torque requirement at the expense of power in first gear as well as satisfy power requirement at high speed in the fourth gear.

Thus, allowing us to use a cheaper and low power consuming motor to reach the same design criteria.

5.6 Motor Selection-

Now consider a motor of 1 kW, 48 V, 18 Nm

1^{st} gear torque = 18 x 16.5 x 0.6087 = 180.783 Nm

2^{nd} gear torque = 18 x 10.3 x 0.6087 = 112.8529 Nm
3^{rd} gear torque = 18 x 7.4 x 0.6087 = 81.0788 Nm
4^{th} gear torque = 18 x 5.2 x 0.6087 = 56.9743 Nm Calculated torque value far exceeds the required torque value as, 180.783 Nm > 156.7996 Nm.
Hence, the motor will be sufficient in the context of torque

6. MOTOR-

1. Motor type- BLDC Permanent Magnet Inner Rotor Motor
2. Motor Design- Single Axle
3. Rated Power- 1000W (Peak)
4. Rated Voltage- 48V
5. No-load rpm- 3000

Fig 6.1 - 1 KW motor

Assume, the full load RPM of the motor is 2500.
Considering real world conditions, the average speed in the city is around 40 kmph. The highway is 60 to 80kmph. Hence, we shortlist a top speed of 80kmph to allow the vehicle to perform up to the mark even on highways and fulfill the owner's need to its fullest.

6.1 Need of Transmission-

A vehicle's transmission system aids in the transmission of mechanical power from the source to the wheels, resulting in kinetic energy. The system's entire setup aids in maintaining the vehicle's cruising speed without interfering with its performance. A transmission uses gear ratios to convert speed and torque from a rotating power source to another device. The transmission decreases the greater motor speed to the slower wheel speed, resulting in increased torque. Transmission losses in a vehicle should be minimized to achieve maximum efficiency. A suitable transmission approach should be devised for this, taking into account vehicle requirements and dynamics [1]. For this reason, we've decided to leave the bike's gearbox alone. Being the most suitable drive train, it has following advantages-

6.2 Advantages of Gear box-

- Cheaper to maintain – Manual transmission vehicles require less maintenance and generally maintenance and repairs end up being significantly less costly.
- The vehicle is more engaging for the driver.
- Motor life will increase as there will be a minimum load on the motor.

- A shifting of conventional bikes to E-bike is more gradual as a rider is more used to the gearbox.

6.3 Observed (collected) data-

1. Primary reduction - 2.045:1
2. Secondary reduction - 2.55:1

Gear Ratios -

1. First gear: 3.173:1
2. Second gear: 1.98:1
3. Third gear: 1.423:1
4. Fourth gear: 1:1

For a speed of 80 kmph in 4th gear,

Tire Specifications: 2.6” (sidewall) x 16” (rim dia.)

Rim diameter = 16x25.4 = 406.4 ≈ 407mm

Sidewall height = 2.6 x 25.4 = 66.04 mm

Total wheel diameter = 407 + (2 x 66.04)

=539.08 mm

= 539 mm

Wheel radius = 539/2 = 269.5 mm

Circumference of wheel = π x d

=π x 539

= 1693.318 mm

= 1693.32 mm

RPM at 80 kmph = (22.22 x 60)/ 1.693

= 787.477 rpm

Final drive output speed without motor primary reduction-

Wheel RPM = 2500 / (2.045 x 2.55 x 1)

= 479.409

Hence required reduction (r) is, r

X787.477=479.409

r = 0.6087

Hence, we need to add a reduction of 0.6087

So, final drive at 4th gear will be- 0.6087

x 2.045 x 2.55 x 1 = **3.1742**

Here,

0.6087:1 ➞ Motor shaft to crank drive

2.045:1 ➞ Crank drive to gearbox input

1:1 ➞ Internal reduction ratio (Gearbox)

2.55:1 ➞ Gearbox output to wheel sprocket

Hence, we get overall 4th gear ratio of 3.1742 we get rpm at 4th gear = **786.41** rpm

But this defines an ideal condition

To account for rpm fluctuations of motor, we design the reduction ratio so far as to attain a wheel at wheel rpm (n) of 800 r x 800 = 479.909 r = **0.5998**

so, we add a sprocket-based drive with a ratio of 0.5998 between motor shaft and crank drive we hence get a primary total reduction of

0.5998 x 2.045 x 2.55 x 1 = 3.1278

Hence, overall gear ratio on 4th gear = **3.1278:1**

This concludes the gear ratio calculations.

7. CHAIN CALCULATIONS-

X= 232 mm

P = 8.5

T1 = 22

T2 = 37

∴ G = 0.599: 1

No. of links

$$k = \frac{T1+T2}{2} + \frac{2x}{p} + \left(\frac{p}{x}\right)\left[\frac{(T2-T1)}{2\pi}\right]^2$$

$$= \frac{22+37}{2} + \frac{2(232)}{8.5} + \left(\frac{8.5}{232}\right)\left[\frac{(37-22)}{2\pi}\right]^2$$

= 29.5+54.58 + 0.208 k

= 84 links

Length of chain

$$L = \frac{p}{2}(T1 + T2) + 2\,x + \left(\frac{p}{2}\operatorname{cosec}\frac{180}{T1} - \frac{p}{2}\operatorname{cosec}\frac{180}{T2}\right)$$

$$= \frac{8}{2}(22+37) + 2 \times 232 + \left(\frac{8.5}{2}\operatorname{cosec}\frac{180}{22} - \frac{8.5}{2}\operatorname{cosec}\frac{180}{37}\right)$$

$$= 250.75 + 464 + \frac{(29.86 - 50.11)}{232}$$

L = 714.66 mm

Fig 7.1 Component Placement

8. Battery-

Where internal combustion engine bikes get energy from burning petrol or diesel, an electric vehicle gets its power directly from a big pack of batteries. These are much like a scaled-up version of the lithium-ion (Li-ion) battery in your mobile phone.

EVs don't use a single battery like a phone, they use instead a pack which is composed of thousands of individual Li-ion cells working together. When the bike is charging up, electricity is used to make chemical changes inside its batteries. When it's on the road, these changes are reversed to produce electricity batteries undergo cycles of 'discharge' that occur when driving and 'charge' when the bike is plugged in. Repeating this process over time affects the amount of charge the battery can hold. This decreases the range and time needed between each journey to charge. Most manufacturers have a three to five-year warranty on their battery. However, the current prediction is that an electric vehicle battery will last from 6-8 years before they need to be replaced.

Lithium ion (Li-ion) batteries are now considered to be the standard for modern battery electric vehicles. There are many types of Li-ion batteries that each have different characteristics, but vehicle manufactures are focused variants that have excellent longevity. Compared to other mature battery technologies, Li-ion offers many benefits. For example, it has excellent specific energy (140 Wh/kg) and energy density, making it ideal for battery electric vehicles. Li-ion batteries are also excellent in retaining energy, with a self-discharge rate (5% per month) that is an order of magnitude lower than NiMH batteries. However, Liion batteries also have some drawbacks as well. Comparatively, Li-ion batteries have been a very expensive battery technology. There are also major safety concerns regarding the overcharging and overheating of these batteries. Li-ion can experience a thermal runaway, which can trigger vehicle fires or explosions. There had been several instances where the Tesla Model S, which utilized Liion batteries, had infamously caught on fire due to issues with fluctuating charging or damage to the battery.

However, great efforts have been made to help improve the safety of vehicles that use Li-ion batteries. Nowadays, most of the EV's that we see on the road are made up of Lead Acid batteries. But, because of the many advantages of Li-ion batteries we have decided to use it in our retrofitted bike.

- Pros and Cons of Lead acid batteries and Li-ion batteries-

Parameters	Lead Acid Batteries	Li-ion Batteries
1.Energy Density (Wh/L)	80	250
2.Specific Energy (Wh/kg)	30	150
3.Regular Maintenance	Yes	No
4.Initial Cost	Low	High
5.Life Cycle	500 @ 50% DoD	2000 @ 70% DoD
6.Temperature Sensitivity	Degrades Significantly above 25 degrees Celsius	Degrades Significantly above 45 degrees Celsius
7.Voltage Increments	12 V	3.2 V
8.BMS Required	No	Yes
9.Fast charging available	No	Yes

For an electric vehicle to be successful largely depends on the energy storage system and it is the lithium-ion batteries that serve the properties that match with a list of specific requirements such as high energy density, decent power capabilities as well as longer life. Lithium-ion batteries, like any other battery, store energy chemically and release the same electrically. Inside, lithium- ion cells allow large amounts of energy to be squeezed into a very small package that enables faster energy extraction faster than any other battery. Liion batteries qualify to be among the top contenders to power electric vehicles. Li-ion battery packs are designed with a closure with battery cells in a variety of form factors such as cylindrical, prismatic (flat rectangle), pouch (Liion polymer, soft-pack polymer, lithium polymer, Li-Po cells) as well as protection electronics to prevent battery abuse scenarios

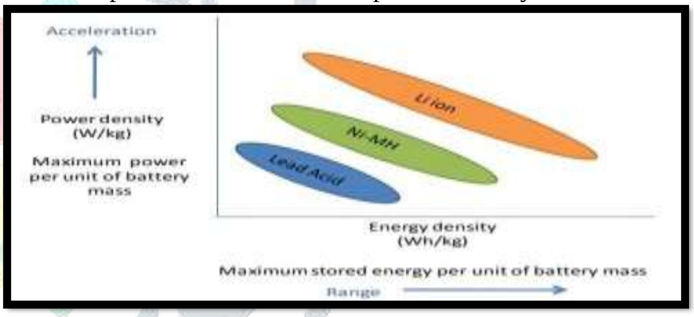


Fig 8.1 Graph between Power density (W/Kg) and Energy Density (Wh/kg) Battery capacity is measured in either Amp Hours (Ah) or kilowatt hours (kWh). The amount of energy used, known as the depth-of-discharge or DOD, is taken as a percentage % of total battery capacity. As a general guide, lithium (LFP) batteries are designed to be discharged up to 90% total capacity (10% SOC) while the traditional lead acid batteries are generally not discharged more than 30-40% on a daily basis, unless in emergency backup situations. It is recommended to set a maximum depth of discharge to no more than 40% for lead-acid and lead-vehicle Bon batteries, and a maximum of 70% in backup situations. Lithium batteries on the other hand can generally be discharged to 70-80% on a daily basis, and up to 95-100% in backup situations

8.1 Proposed Battery Plan

Since we have considered a motor of 1KW and 48V we can calculate the current required by using the formula-

Power=Voltage*Current

Hence can calculate as follows,

1000=48*I

I = Rated current

=20.83A

~21A

Since we have a target top speed of 80 Km/Hr and a single cell specification of 3.2V and 6Ah, So, for 48V battery pack:

48/3.2=15 cells in series

And for a desired range of 120Km,

We consider that in 21Ah our bike covers 80Km as our rated current is 21A, so for a 120Km range we have to calculate as follows

21Ah=80Km

X Ah=120Km

So cross multiplying and calculating we get,

X=31.5Ah

By considering various mechanical and electrical losses we make a battery pack of 36Ah Hence, we use 36/6 i.e., 6 sells in parallel

Hence total cells required for constructing this battery pack are **6*15=90** cells in a combination such that 15 cells are in series and 6 are in parallel

Fig 8.2 Regular 3.2V 6Ah cell

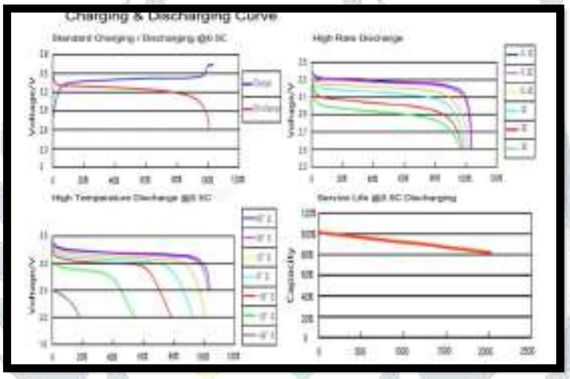


Fig 8.3 Charging and discharging curve

8.2 Proposed Battery Pack Design-

As our project is to retrofit an electric drive train in existing motorbike chassis, we have to adjust or accommodate our battery pack in the available space. So, we will design our battery pack in two stacks, to fix it where the already petrol tank is situated.

1. 8 x 6 = 48 cells
2. 7 x 6 = 42 cells

By combining both the stacks we will get our desired battery pack of 15 x 6 cells.

To achieve this configuration, following designs are to be made-

Fig 8.4 Battery Stack 1

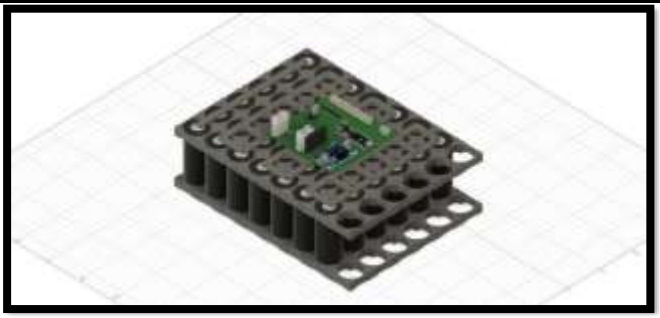


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Fig 8.5 Battery Stack 2

Above figure indicates the battery pack of 7 x 6 cells with battery holders.

The electronic PCB mounted above the pack is called a BMS. The function of BMS is as follows-

1. Provide battery safety and longevity, a must-have for Li-ion.
2. Reveal state-of-function in the form of state-of-charge and state-of-health (capacity).
3. Prompt caution and service. This could be high temperature, cell imbalance or calibration.
4. Indicate end-of-life when the capacity falls below the user-set target threshold.

In short, BMS is the controlling unit for the Li-ion battery

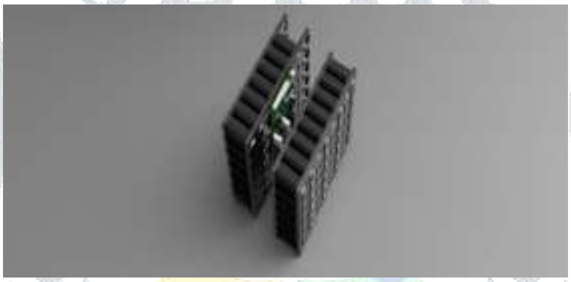

Fig 8.6 Battery Stack (Top view)

The two stacks are placed adjacent like the above figure on the motorbike chassis. The space between these two stacks is reserved for the accommodation of the top tube member, as previously the petrol tank of the original conventional bike was situated there. By doing so, it would be aesthetically better and the C.G. of the motorbike will get balanced

This type of battery box is made to be fitted on the chassis of the bike. The battery box is made up of plain vehicle Bon steel and powdered coated to avoid corrosion by means of environmental conditions. In this battery pack, two stacks are placed adjacent to each other and there is a space between it such that the box will accommodate on the top tube previously where the petrol tank was situated.

Use of a battery box is as follows-

1. To provide protection from environmental conditions.
2. To make the Li-ion battery look aesthetically better.
3. To prevent short circuits. To avoid the direct human contacts to the battery.

8.3 Steps for making a battery pack-

As mentioned above, a 36 Ah Li-ion battery pack is to be manufactured. For those 90 cells of 3.2 V and 6000 mAh are to be arranged in series and parallel.
Manufacturing of a Li-ion battery consists of following stages-

1. Selection of cells and arranging them in series and parallel.
2. Spot welding of nickel strip on the cells.
3. Joining the BMS connections.
4. Proper insulation and installation of the battery pack.

I. **Selection of cells and arranging them in series and parallel-** Cells used - FBTech 3.2 v 6000 mAh 3C cell.
Life cycle – 2000

Arrangement - 15 series and 6 parallel in two stacks (As shown in figure 8.6)

II. *Spot Welding-*

A 95% pure nickel strip of width 10 mm and thickness 0.5 mm is to be used for spot welding. Current rating of a single nickel strip is 10 A. So, we have to join multiple nickel strips in parallel to satisfy our current requirement.

Spot welding is done by using a typical DC spot welder of rating 50 A 3 V. Two-three spots are to be made on each cell to confirm that it should not become loose or get removed.

III. *Joining the BMS connection-*

A BMS of 80 A is to be used for the battery pack. There are a total 17 tapings on the BMS. One each for overall positive and negative. Remaining 15 will be joined at each series connection. Also, there is a thermal sensor in the BMS which is to be inserted in the battery pack.

IV. **Insulation for battery pack-**
After doing all the connections, both two stacks will be properly insulated. First layer is of the thermal insulation tape. Over it the battery pack will get covered by the shrink tube. After that, a solid steel box is to be made for covering the whole battery pack.

Fig 8.9 Battery Box Placement

9. ANALYSIS-

1. Chassis analysis for battery pack weight-

We have applied a force equivalent to weight of battery pack on the top tube of the chassis while the bottom tube is fixed. A Fusion 360 analysis was performed and the following results are obtained.

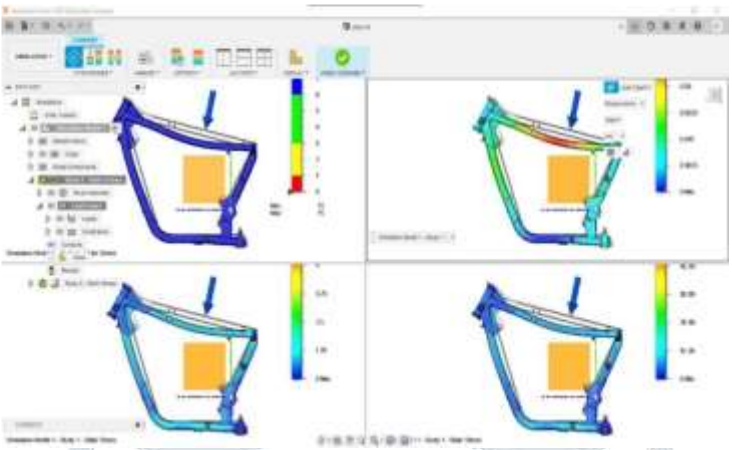

Fig 9.1 Top tube Analysis

2. Chassis analysis for motor and gearbox weight-

We have applied a force equivalent to the weight of motor + gearbox on the bottom tube of the chassis. A Fusion 360 analysis was performed and the following results are obtained.

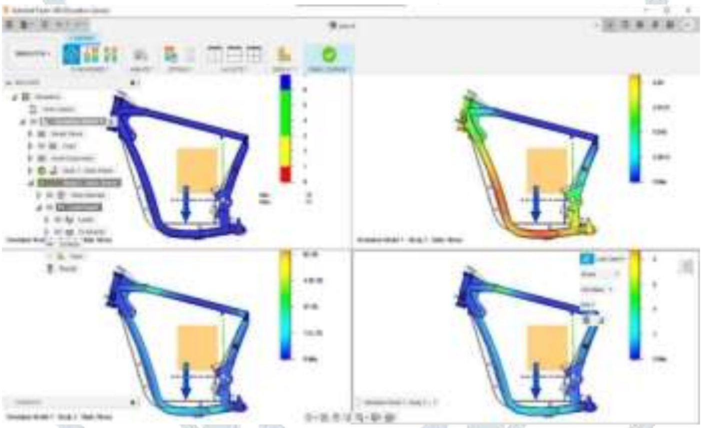

Fig 9.2 Bottom tube Analysis

As it can be seen that the chassis shows minimum deformation and stresses generated is also within the limits. Hence, we can say that the weight of the components can be easily handled by the chassis and therefore, the design is safe.

10. CONTROLLER -

Electric vehicles brushless DC motor controllers provide efficient, smooth and quiet controls for electric VEHICLE, electric motorcycle, scooter conversion, etc. Electric vehicles brushless motor controllers output high taking off current, and strictly limit battery current. Motor speed controller can work with a relatively small battery, but provides good acceleration and hill climbing. BLDC motor speed controller uses high power MOSFET, PWM to achieve efficiency 99%. In most cases, Powerful microprocessors bring in comprehensive and precise control to BLDC motor controllers. This programmable brushless motor controller also allows users to set parameters, conduct tests, and obtain diagnostic information quickly and easily.

Features of controllers:

- Specifically designed for electric VEHICLE and scooter.
- Intelligence with a powerful microprocessor.
- Synchronous rectification, ultra-low drop, fast PWM to achieve very high efficiency.
- Electronic reversing.
- Voltage monitoring on 3 motor phases, bus, and power supply.
- Voltage monitoring on voltage source 12V and 5V.

- Current sense on all 3 motor phases.
- Current control loop.
- Hardware overcurrent protection.
- Hardware over voltage protection.
- Support torque mode, speed mode, and balanced mode operation.
- Configurable limit for motor current and battery current.
- Battery current limiting available, doesn't affect taking off performance.
- More startup current, can get more startup speed.
- Low EMC.
- LED fault code.
- Battery protection: current cutback, warning and shutdown at configurable high and low battery voltage.
- Rugged aluminum housing for maximum heat dissipation and harsh environment.
- Rugged high current terminals, and rugged aviation connectors for small signals.
- Thermal protection: current cut back, shutdown on high temperature.
- Configurable 60 degree or 120-degree hall position sensors.

Support motors with any number of poles.

The controllers on most vehicles also have a system for regenerative braking. Regenerative braking is a process by which the motor is used as a generator to recharge the batteries when the vehicle is slowing down. During regenerative braking, some of the kinetic energy normally absorbed by the brakes and turned into heat is converted to electricity by the motor/controller and is used to recharge the batteries. Regenerative braking not only increases the range of an electric vehicle by 5 - 10%, it also decreases brake wear and reduces maintenance cost. Modern controllers adjust speed and acceleration by an electronic process called pulse width modulation.

11. CHARGER -

In order to utilize the battery to its maximum capacity the battery charger plays a crucial role. The remarkable features of a battery charger are efficiency and reliability, weight and cost, charging time and power density. The characteristics of the charger depend on the components, switching strategies, control algorithms. This control algorithm can be implemented digitally using a microcontroller. The charger consists of two stages. First, one is the AC-DC converter with power factor correction which converts the AC grid voltage into DC ensuring high power factor. The later stage regulates the charging current and voltage of the battery according to the charging method employed.

The charger can be unidirectional i.e., can only charge the EV battery from the grid or bidirectional i.e., can charge the battery from the grid in charging mode and can pump the surplus amount of power of the battery into the grid. This is a lithium-ion battery charger circuit (48v 5A) for a 48v 25Ah battery as shown in fig. The circuit given here is a current limited lithium-ion battery charger built around the famous variable voltage regulator IC LM 317. The charging current depends on the value of resistor R2. Resistor R3 and POT R4 determine the charging voltage. Transformer T1 steps down the mains voltage and bridge D1 does the job of rectification. C1 is the filter capacitor. Diode D1 prevents the reverse flow of current from the battery when charger is switched OFF or when mains power is not available.

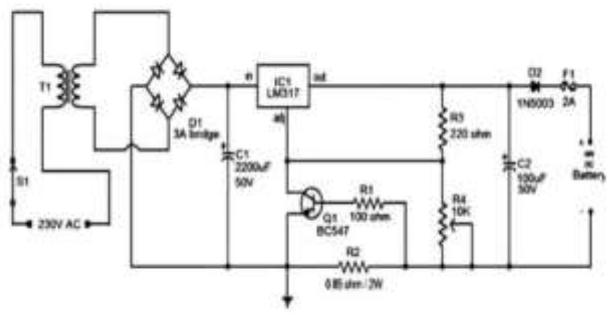

Fig 11.1 Charging Circuit

12. COST ESTIMATION

Electrical Equipment's Cost-

Sr. No.	Component Name	No. of Components/ Quantity	Cost in Rs.
1.	LiFeO4 Cells	90	13908
2.	BMS	1	1800
3.	Holders	90 of (2x1)	450
4.	Nickel Strip	5 meters	200
5.	Shrink Tube	3 meters	150
6.	1 KW 48V BLDC Motor	1	4366
7.	1 KW 50 A Controller	1	3540
8.	Anderson Connectors	2	200
9.	Wires	10 meters	120
10.	Throttle	1	300
11.	Key Switch	1	200
12.	Display	1	400
Total - 25634/-			

Table 3: Cost estimation for electrical components

Sr. No.	Component name / Parameter	Cost in Rs.
1.	Old Jawa Yezdi 250	18000
2.	Regular maintenance of moving parts	1500
3.	Jawa unused spares to sell	(-6000)

4.	Sprocket and chain	2500
5.	Miscellaneous	4000
		Total – 20000/-

Table 4: Cost estimation for mechanical components

***Note-** All the prices are dependent on geographic locations and market conditions. It may vary.
Hence, total cost of the project is = 25634 + 20000
=45634

Fig 12.1 Final bike after rendering

The above figure shows the actual retrofitted bike which we have to supposed to make.

13. EXPECTED OUTCOMES -

1. Providing data supporting retrofitting as a quick and sustainable solution for the move from conventional vehicles to complete electrified vehicle.

2. To provide a geared solution for smooth transition in riding experience while shifting from IC engine bike to electric bike.

To validate that the geared drivetrain provides better results than a single speed drivetrain in more economical way.

6. CONCLUSIONS

We are trying to solve the problems faced in the conventional motorcycles and also the currently available electric motorcycles in the competing market. By providing a gearbox-based solution, we can reduce the cost of the vehicle considerably as it utilizes nearly half the number of cells as compared to a single speed drivetrain, while also reducing the size and weight of battery pack. Noteworthy reduction is also achieved in the size and price of the required motor as the motor power required drops from 3.5 KW to 1 KW.

The reduced weight will also aid in the ease of handling the motorcycle while the gearbox placed at the bottom helps in reducing the center of gravity of the vehicle. Hence, a gearbox-based solution leads too much better parameters as compared to a single speed drive train

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