Fabrication of Parallel Hybrid Electric Two Wheeler

Anupam Surana [*], Sreshtha Roy[**]

[*] B.tech, Department of mechanical and automobile engineering, Faculty of Engineering Christ (Deemed to be University)

[**] B.tech, Department of mechanical and automobile engineering, Faculty of Engineering Christ (Deemed to be University)

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Abstract- A "Parallel Hybrid electric Two-wheeler" is a vehicle that depends not only on electric energy from the batteries but also on an internal combustion engine. This particular system is much more advantageous than the conventional only gasoline run engine. The objective is to fabricate a system that can be powered by both battery and gasoline, making the vehicle stand out from the rest. The system will be providing advantages like fuel economy and toned down environmental impact, when compared to the traditional vehicles. Hybrid systems in vehicles combine electric hub motor, battery, control system with an internal combustion engine to reduce toxic products and achieve increased fuel economy. Thus, the vehicles are best for the ever increasing urban localities with soaring traffic.

Index Terms- Hybrid electric vehicle, hybrid electric two wheeler, comparison between HEV and conventional vehicle

I. INTRODUCTION

In the recent times, after a period of more than a century, the automotive industry and other vehicles in use are posing various challenges causing grave concerns for the health of both Mother Earth and her children. Moreover, symptoms of the increasing difficulties due to anthropogenic climatic changes adds to the importance of reducing the Green House Gas (GHG) emissions from all possible sources. The automotive sector is a major donor towards the degradation of the air quality in the environment. Depending upon the fuel type, driving style and road conditions, a medium sized vehicle emits about 411 grams of CO2 per mile of travel on an average, leading to around 4.7 metric tons of CO2 yearly. The transportation sector in INDIA is accounted for approximately 11.7 percent of total GHG emissions in 2017. The internal combustion engines driven automobiles was one of the greatest inventions of mankind under engineering achievements in the end of nineteenth century. The traditional vehicles powered by internal combustion engines give out good performance and provide lengthy driving range. The quality of performing consistently well, ease of use and availability of cheap fuels led to the growth and acceptance of the conventional vehicles. However, there are two sides of the same coin. On the other side, these conventional vehicles have been posing great threats to fuel economy, environment and human health. Controlling and reducing carbon emissions are the trending goals of today's design. Hybridization of the traditional vehicles with latest electric motors may luckily enhance the fuel efficiency overall and also reduce emissions. Many countries have already set targets towards reducing conventional vehicles with electric vehicles for the betterment of the environment and reduce global warming by controlling the GHG emissions contributed by the transport industry. Considering the current situations in INDIA, an organised and fuel efficient two wheeler has to be developed. Electric vehicles on contrary, to ICE vehicles are more efficient in converting the stored energy. Regenerative braking can be used to compensate the energy losses caused due to braking. An electric vehicle has an efficiency of about 80 percent onboard whereas a petrol engine uses 15 percent of the fuel content. Hybrid technology is promising, if worked upon, as it has multiple different energy sources. The energy sources could be used separately or simultaneously for customisable uses. The main limitation of a hybrid system is the cost. The cost, in itself, makes it a system which is unattainable by a lot of people. India is targeting to have an all-electric car fleet by the year 2030 with an aim of decreasing the fuel import and running cost of vehicles. As a beginning point in this path, Govt. of India has launched the *National Electric Mobility Mission Plan* (NEMMP)-2020 in the year 2013. It intends to achieve national fuel security by promoting hybrid and electric driven vehicles in the country. The pioneering target is to reach sales of 6-7 million hybrid and electric vehicles per year introducing from 2020, out of which 4-5 million are anticipated to be two-wheelers.

II. TYPES OF HYBRID VEHICLES

This is where the concept of hybrid systems comes into place.
There are four main types of hybrid vehicles based on types by degree of hybridization.
They are:-

- Full Hybrid
- Medium Hybrid
- Mild/Micro Hybrid
- Plug-in Hybrid

A Full Hybrid Electric Vehicle can run either on the IC Engine or Power train, or combination of both IC Engine and Power train. The system monitors the working of the entire system, concluding either motor or engine, or both should be running. The IC Engine will be shut down when the electric motor has the sufficient energy to provide the power. To perform such operations a high capacity battery pack is needed.Toyota, the Japanese automobile giant which was very efficiently and successfully involved in developing and promoting greener cars

in their early 1990s. It was in 1997 that Toyota revealed one of their most successful hybrid vehicles ever to be sold globally ever called the Toyota Prius It was first introduced into the Japanese market and then to the rest of world. In its first year of introduction it achieved a sales of 18000 which was surprisingly very good for a hybrid vehicle at a time when the general public were agnostic of the developments taking place in the area of alternate automobile energy sources.

In medium hybrid vehicle the amount of electric power required is smaller compared to full hybrid vehicle. In this system the engine is used for primary power with a electric motor connected in parallel connection to a largely conventional electric power train. The Electric Motor is placed between the engine and transmission and usually act as a. very large starter motor. It not only operates when the engine needs to be shut down, but also when the driver requires extra power or extra torque for required driving condition. The electric motor can also be used to re-start the IC engine, deriving the same benefits from shutting down the main engine at idle, while the enhanced battery system is used to power accessories of the vehicle. Based on medium hybrid type is Mazda's e-4WD system, derived from the Mazda Demio. It is a limited production electric vehicle only for the Japanese market which includes a 346 Volt 20KWh lithium ion Battery with up to 200km (124mi) driving range. The forward drive vehicle has an electric motor which can also drive the rear wheels of the vehicle when extra traction is needed. The system is completely disengaged in other driving conditions, thus it does not enhance with the performance or economy.

Mild hybrids are the conventional vehicles with huge starter motors in it which allows the engine to be turned off easily whenever the car is braking, or stopped, and re-start quickly and elegantly. During the restart, the larger motor of the electric vehicle is used to spin the engine and to operate the rpm before injecting any fuel to the system. While in other hybrid vehicles, the motor is generally used for regenerative braking to recapture energy which is lost, even though there is no motor assist and Electric Vehicle mode at all. Thus, most of the people do not consider these variant of hybrids, as there is no electric motor to drive the vehicle, and also these type of vehicles does not achieve the fuel economy compared to real hybrid models

The accessories such as Air Conditioners, also continues to run on electrical power while the engine is in turned off condition which is normally only driven when the engine is running condition. Moreover, the lubrication system of IC Engines are normally less effective just after the engine starts. Since this is upon the initial start-up condition that the maximum of engine wear occurs. The frequent turning ON and OFF of such systems would reduce the lifespan of the engine. Also, the very frequent start and stop cycles might reduce the engine's ability to operate at its maximum temperature, therefore reducing the engine's efficiency. BMW were the first one to get succeeded for combining the regenerative braking with the mild hybrid system in their 1-series model. The Hybrid Vehicles can be grouped within a classification of charge assisting the energy storage system in these vehicles which is to remain within a confined region of state of charge (SOC). The hybrid propulsion algorithm is designed in such a way that on average, the SOC of energy stored in a system will more or less return to its initial condition after a complete driving cycle. A Plug-in Hybrid Electric Vehicle (PHEV) is a type of full hybrid vehicle which is only able to run in the electric mode, with huge batteries and the ability to recharge quickly (compared to other hybrid or electric vehicles) from the electric power grid. The main benefit from this particular system is that they can be operated on conventional power sources for daily commuting, and meanwhile also have the extended range of a hybrid for long trips.

Due to all the developments which are taking place during these times, the world has started to take hybrid vehicles much seriously as an alternative to conventional vehicles. Based on configuration hybrid vehicles can be classified into three different types:-

- Series Hybrid Vehicle
- Parallel Hybrid Vehicle
- Series-Parallel hybrid Vehicle

In the **Series Hybrid** vehicle configuration (as shown in figure 1), energy from the IC Engine generates electricity and an electric motor drives the vehicle. This configuration allows improved engine efficiency with the engine de-coupled from direct propulsion. The main disadvantage is the significant electric losses caused by the energy conversions between mechanical and electrical energies. In addition, the series configuration demands two electric motors (a generator and a motor) of high capacity which potentially increase the cost and add challenges to packaging in the engine bay area. Figure 1 below depicts a schematic of a generic series HEV power train. Note that in this and all subsequent figures that a solid line denotes a mechanical connection while a dashed line denotes an electrical connection. Several automotive OEMs examined the possibility of development programs for series HEV. Some of the most notable are the Mitsubishi ESR, Volvo ECC, and BMW 3 Series.

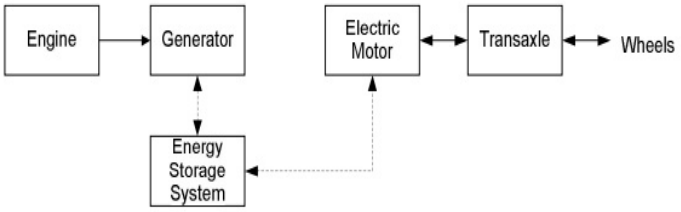

Fig. 1: Series hybrid vehicle structure

In the parallel hybrid vehicle configuration an electric motor and an IC Engine are connected to the drivetrain and provide propulsion power. With the electric motor, this configuration can reduce the ICE size compared with a conventional vehicle, without compromising the vehicle performance. The energy efficiency of the ICE can also be improved with assistance from the electric motor. Some early developed parallel HEVs include the BMW 518, Citroen Xzara Dyn-active and Saxo Dynavolt, Daimler-Chrysler ESX 3, Fiat Multipla, and the Ford Multiplia and P2000 Prodigy. A generic parallel architecture is depicted in the Figure below

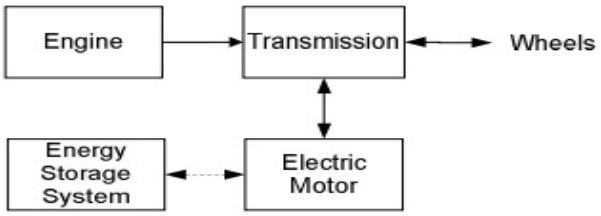

Fig. 2: Parallel hybrid vehicle structure

In an e-CVT HEV powertrain, the vehicle can operate as a series hybrid, a parallel hybrid, or a combination of the two (as shown in figure 2). The keys to this configuration are the presence of two motor/generators and the mechanical and electrical connections between the two. The mechanical connection between the engine and electric machines is usually accomplished by planetary gear sets known as power-splitting device (PSD)

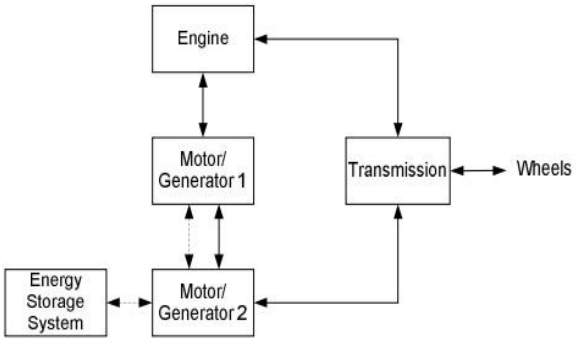

Fig. 3: Series –Parallel vehicle structure

Toyota and Ford utilized the one-mode power split configuration with a single e-CVT configuration; it has a single planetary gear and the input split configuration is relatively simple with only one pure mechanical path. GM, Renault and others have introduced the two mode power split configuration with two e-CVT configurations, which has multiple planetary-gears and an input/compound split function that is more complex. It however offers different possible transmission configurations which increases energy efficiency and improves performance under different driving conditions.

III. DESIGN AND FABRICATION OF THE VEHICLE

After the research was completed for the project, the idea was straight forward. We made up a plan chronologically. Each week was allotted for a particular job to be completed. The actual work done can be categories into three sections:-

- Process Methodology
- Parts of Hybrid Electric Two Wheeler
- Fabrication of Parallel hybrid Vehicle

Process Methodology-

The literature survey and the studies done by different researchers helped us in getting a clear idea to which we committed. Further research was done to get a proper idea of how these theoretical values and formulations can be applied to gain a working model of the parallel hybrid system. The struggle of altering the chassis was greatly overcome with design upgrades and other factors that reside along with it. The sourcing of components were part successful and where we lacked in resources, we tried to make up that with home brewed items. The components such as the generator, motor, batteries and the motor controller were fitted to the chassis and the vehicle was tested.

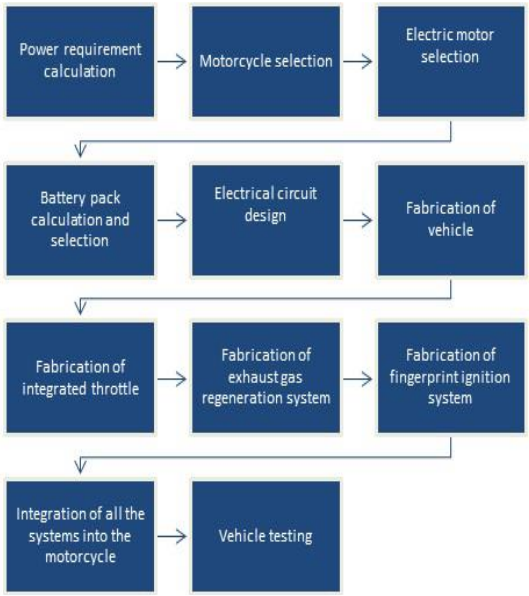

Fig. 4: Process methodology

Parts of Hybrid Electric Two Wheeler-

1. Motor-

1.5KW Brush less Direct Current (BLDC) Motor (as shown in figure 3.10) has been used to drive the vehicle because of its excellent speed vs torque characteristics and high dynamic response and efficiency. It has longer operating life due to lack of electrical and frictional losses. Since there are no brushes the motor is very silent during its operation also the speed of rotation can be easily varied with a motor controller and a hall-effect throttle. It is located in between the Engine and Rear Wheel as shown in figure 5

Fig. 5: Bldc Motor

Specifications-

Type: Permanent Magnet BLDC
• Voltage (Volts): 48
• No load Current (Amperes):- 4
• Rated Current (Amperes): 45
• Peak Current (Amperes): 70
• Rated Speed (RPM) : 3000 ± 100

• Rated Torque (Nm) : 5.2
• Max Output Torque (Nm) : 400 percent of rated value
• Rated Power (W): 1500
• Max Output Power (W): 2500
• Efficiency: Greater than 87 percent on full load and full rpm
• Motor weight (kg): 5.4
• Insulation class: B
• No of Rotor poles: 8
• No of Stator poles: 12
• Star connected windings for higher torque
• Hall Sensor arrangement: (Three sensors at 120 Electrical degrees)
• Type: Bipolar Hall Effect Digital Position Sensor IC (SS41)
• Wide operating Voltage Range (Volts):- 4.5 to 24
• Very low current consumption (milliamperes): 20
• Operating Temperature (°C): -40 to 150

Fig. 6: hybrid power train arrangement

2. **Motor Controller-**

The motor controller is the brain of electric and hybrid electric. It is in the motor controller were the signals are processed and sent to the motor. This is the junction at which all the input signal reaches and the output signal are sent to the respective electric motor. The other function of the motor controller is that they can be also used to add fuses which will prevent all types of electrical overloading conditions Motor control unit is a device which is used to control the outcomes of a motor. Almost all the functions of a MCU are predetermined and coded into the micro controller from the real time analysis and experiments. It can include processes like limiting the torque to the motor, regulating the right speed as per the user's requirement, protection against over loading and faults, starting and stopping the motor, reversing the direction of rotation, cutting off the power to the motor in times of braking, collecting and putting back the regenerated electricity and various other functions so as to protect the battery and motor's life and provide the desired requirement for the user. We have multiple ECU's in an HEV to have control over the complete architecture of an HEV which is then controlled by an individual ECU .The complete process is successful with the continuous rectification done against the actual behaviour from the command given by the user. This can be achieved with help of a feedback loop. The input signal which is nothing but the desired behaviour is compared with the actual behaviour of the system to find the error and this is put back into the control element through feedback loop then the desired output is achieved.

Fig. 7: Motor controller

Specifications-

• Rated DC Voltage (Volts): 48
• Over Voltage Cut-off (Volts): 58
• Under Voltage Cut-off (Volts): 41
• Commutation Angle (Degrees): 120
• Rated Power (Watts): 1500
• Rated Current (Amperes): 50
• Operating Temperature (°C): -20 to 80
• Protection Class: IP 33
• Brake De-energize: High
• Throttle voltage: 1V to 4.5V
• Number of Mosfets: 24
• Type of Mosfets :- N-Channel Mosfet (HY3408AP)
• VDSS (Drain Source Voltage)(Volts): 85
• Maximum Junction Temperature(°C): 175
• Id (Continuous Drain Current) (Amperes): 140
• Maximum power dissipation (Watts): 250
• Operating Temperature (°C):- -50 to 175
• Braking Type: High level Braking / Low level Braking

3. **Motorcycle: TVS Jive-**

The motorcycle TVS Jive (as shown in figure 8) is particularly used for its automatic clutch. The gearbox is a epicyclic type and there is no clutch cable to shift gears, which means the centrifugal clutch helps in shifting of gears.

Fig. 8: Motorcycle (TVS JIVE)

Specifications-

• Displacement - 110 cc
• No. of Cylinders - 1
• Maximum Power - 8 BHP @ 7500 RPM
• Maximum Torque - 8 Nm @ 5500 RPM
• Bore - 53 mm
• Stroke - 49 mm
• Valves Per Cylinder - 4
• Fuel Delivery System - Carburettor
• Fuel Type - Petrol
• Spark Plugs - 2 Per Cylinder
• Gearbox Type - Manual
• No. of Gears - 4
• Transmission Type - Chain Drive
• Clutch – Automatic

4. Battery-

Lead acid batteries are used to power the electric motor of rating 12v 35 ah. 4 batteries are connected in series (as shown in figure 9) to have a total output of 48v 35ah, hence a total power of 1680 watts is delivered by the battery to drive the1500 watts motor. Each battery weighs around 9 Kgs making a total weight of 36 Kgs. The vehicle can run approximately a distance of 50 Km with total load of 300 Kgs. Though lead acid batteries are heavier and bigger compared to li-ion batteries but due to low maintenance and low cost it has been used.

Fig. 9: Lead acid battery

Advantages:-

• It is available in every shapes and sizes.
• It does not require any regular maintenance.
• It is best in terms of reliability.
• It withstands slow, fast and overcharging.
• It can withstand long term inactivity with or without solvent.
• It has best value for power and energy per KWH.
• It offers longest life cycle compared to other batteries.
• About 97 percent of lead can be recycled in new batteries.
• It is inexpensive to manufacture, low cost per watt-hour.
• It offers low self discharge, lowest among rechargeable batteries.
• It offers good performance at all temperatures.

Fabrication of Parallel hybrid Vehicle-

This project aims on developing a parallel hybrid electric motorcycle where both the IC engine and the electric motor will provide power to the rear wheel of the motorcycle. The project mainly focuses on decreasing air and environmental pollution by integrating the electric motor to the motorcycle and increasing the riding comfort, safety and fuel efficiency (driving range) of the vehicle

Fig. 10: Hybrid electric two wheeler

IV. COMPARATIVE STUDY

FACTORS	TVS JIVE (Petrol)	TVS JIVE (Parallel Hybrid)
Max power (bhp@rpm)	8 bhp @ 7,500 rpm	8 bhp @ 7,500 rpm + 2 bhp
Max torque (Nm@rpm)	8 Nm @ 5,500 rpm	8 Nm @ 5,500 rpm + 5.2 Nm
Kerb weight (kg)	115 kg	180kg
Fuel type	Petrol	Petrol + Electric
Fuel tank capacity	15 litres	15 litres + 48V 35AH
engine type	single cylinder, ic engine	bldc motor 1500 watts
Range(km)	928 Km	928 + 50 kms
Battery/Fuel Tank Weight	2 kg	2 + 35 kg
Refuelling Time	5 mins	5 mins + 240 mins
Cost per Unit	75 - 77 / litre	1.48/unit + 75-77 / litre
Fuel Storage Estimated Life	240 months	240 80 months

V. CALCULATIONS

The following calculations were done to select the appropriate BLDC motor for the vehicle-

1. Rolling resistance (RR) -

RR = GVW * Crr
(where GVW is Gross Vehicle Weight and Crr is is Coefficient of Rolling Resistance.)
RR = 180* 0.015
RR = 2.7

2. Grade resistance (GR) -

GR = GVW * sin(x), where x=degree
GR = 180 * sin(10)
GR = 31.25

3. Accelerating force (Fa) -

Fa = M * A, where M is mass and A is acceleration
M = GVW/g , where g is acceleration due to gravity
M = 180 / 9.81
M = 18.34
Fa = 18.34 * 1.724
Fa = 31.6 N

4. Total Tractive Effort (TTE) -

TTE = RR + GR + Fa
TTE = 2.7 + 31.25 + 31.6
TTE = 65.55 N

5. Torque of the Motor (T) -

T = Rf * TTE * radius of wheel
T = 1.15 * 65.55 * 0.2665
T = 20.08 Nm

6. velocity (V) -

V = (p*D*n)/60 (V = 40KMPH=11M/SEC)
11.11 = (3.14*0.533* n) /60
n= 746.89 rpm

7. Power of the motor -

Power = (2*p*n*T)/60
Power = (2*3.14*746.89*20.08)/60
Power= 1569.74 watts

VI. CONCLUSIONS

• The experiment, 'Parallel Hybrid Vehicle with exhaust gas regeneration system, has been dealt as a technology with a significant potential in the future. Since its power source is flexible, vast variety of energy sources can be incorporated into the parallel hybrid system, replacing the IC engine. Because of the dual sets of batteries, the range is extended as well as the life of the battery is increased.

• The incorporation of power source into the system helps in attaining a higher range when compared to pure electric systems. As we know that Indian Government plans to make India an electric nation within the next 10-12 years. So, here the vision is an all electric passenger vehicle like cars, buses etc.

• Hybrid vehicles have long been an idea which took birth even from the conception of the very first automobiles. Using an electric motor to aid the conventional engine of the vehicle is an idea envisioned by the pioneers in the field of automotive technology.

• Many factors including the development of technologies of gasoline as well as diesel engines coupled with the low cost and availability during the time of discovery of these fossil fuels added with the ignorance of people on the harsh environmental effects of these fuels added on advantage for internal combustion Engines which had dominancy over the automotive world for many decades.

• The hybrid is a perfect platform for the transition from fossil fuels to electric energy allowing India to reduce its importing of crude oil and encourage India to make use of available energy as a resource. Thus the 'parallel hybrid two wheeler' stand out even in the hybrid platform.

REFERENCES

[1] R. T. Soni, "Hybrid Electric Vehicle" IOSR Journal Mechanical and Civil Engineering, vol. 12, no. 2, pp. 11-14, 2015.

[2] Jinhyun Park, "Torque Distribution Algorithm for an Independently Driven Electric Vehicle Using a Fuzzy Control Method," Energies, vol. 8, pp. 8538-8561, 2015.

[3] Hengbing Zhao, "Modelling and Analysis of Plug-in Series-Parallel Hybrid," EuropeanBattery, Hybrid and Fuel Cell Electric Vehicle Congress, vol. 1, pp. 1-9,2015.

[4] Xiaogang Wu, "Energy Efficiency and Fuel Economy Analysis of a Series Hybrid Electric Bus in Different Chinese City Driving Cycles," International Journal of Smart Home, vol. 7, no. 5, pp. 354-368, 2013.

[5] M Khairul Bashar, "Design of Series Hybrid Electric Vehicle with Auxiliary Power," International Journal of Advancements in Research and Technology, vol.2, no. 4, pp. 361-368, 2013.

[6] Yinjiao Xing, "Battery Management Systems in Electric and Hybrid Vehicles," Energies, vol. 4, pp. 1841-1857, 2011.

[7] J-P Gao, "Equivalent fuel consumption optimal control," IMechE, vol. 2, no. 23,pp. 1003-1018, 2009.

[8] Junzhi Zhang, "Regenerative Braking System for Series Hybrid Electric City Bus," The World Electric Vehicle Journal, vol. 2, no. 4, pp. 128-134, 2008.

[9] ZanobettiA ; Schwartz J. Air pollution and emergency admissions in Boston , MA J.Epidemol. Community health 2006 (890-895)

AUTHORS

First Author – Anupam Surana, B.tech, Department of mechanical and automobile engineering, Faculty of Engineering Christ (Deemed to be University)

Second Author – Sreshtha Roy, B.tech, Department of mechanical and automobile engineering, Faculty of Engineering Christ (Deemed to be University)