Development of Hybrid Electric Bicycle using Stirling Engine

Mr. Yogesh S. Shete[1*], Prof. S. A. Pawar[2]

[1] PG Student, Department of Mechanical Engineering, FTC, COER, Sangola, India

[2] Head of Department, Department of Mechanical Engineering, FTC, COER, Sangola, India

*Corresponding author

doi: https://doi.org/10.21467/proceedings.118.18

ABSTRACT

In India, these days, the solicitation for electric bicycles continues expanding step by step. Be that as it may, as indicated by the office foundation and in contemplations of India's best electric bikes, it is nearly difficult to utilize such electric bicycles for long excursions till today. Likewise, such bicycles set aside an excess of effort to get completely energized. To limit these downsides, we will see an idea of the crossover bike utilizing the Stirling Engine in this paper. The fundamental explanation for choosing the Stirling motor is, it is eco-accommodating and doesn't need a particular warmth source as a fuel. In straight words, this idea has a place in the law of energy preservation. This paper includes the concept, functions, and testing of the developed model along with an explanation of various tests performed to calibrate the performance.

Keywords: Electric bikes, Sustainable development, battery charging using Alternator, Stirling engine.

1 Introduction

Electric vehicles are now the future of automobiles. There are numerous automotive manufacturers in India. But very few manufacturers are focusing on the production of electric vehicles, especially bicycles. Whereas, In India, the implementation of electric vehicles has almost done throughout the country. But there are numerous limitations in the context of electric vehicles and infrastructure are available. India is facing many issues for the implementation of total electric infrastructure throughout the country. The hybrid vehicle is a solution till India establishes overall electric infrastructure throughout the country. There are different types of Hybrid Vehicles. Generally, a vehicle that uses two or more different fuels to work successfully is called a hybrid vehicle. Hybrid Vehicles are introduced more than two-decade ago in India. Still, there are limited options available in hybrid vehicles. India's automobile sector is one of the largest sectors in Asian countries. Still, the lack of electric infrastructure is a hurdle for any developing country [1]. The author also focuses on the design and development of a Stirling-based electric hybrid bicycle. In actual practice, no such vehicle exists worldwide. Developing such a vehicle alone was a difficult task for the author. The basic idea of this project has emerged by analyzing the facts and figures of electric bikes available in India today. There are many hurdles and limitations for an electric bike in India. Also, it found, electric bikes in India are not to be suitable for long journeys. Some of the best electric bikes in India have a charge range of 120 km per charge, while the batteries take 7-8 hours to charge fully [2].

With the fast expansion in the Indian Automobile market, Electric Vehicles (EVs) are transforming into a promising channel towards further developing air quality, energy security, and monetary freedom. The public authority of India perceives the earnestness to take a gander at economic portability answers for diminishing reliance on imported fuel sources, decreased ozone depleting substance emissions, and alleviate antagonistic effects of transportation with the addition of an unnatural weather change. Taking prudent steps to lessen the disastrous environmental change that undermines the types of this planet can diminish the carbon dioxide emission. Significant undertakings had taken for insignificant utilization of petroleum derivatives for power age, transport drive, loss in energy utilization, and security of carbon sequestration.

Proceedings DOI: 10.21467/proceedings.118; Series: AIJR Proceedings; ISSN: 2582-3922; ISBN: 978-81-947843-6-4

EVs could be the choice to diminish the carbon dioxide gas emission [3].

As the EV market extends, the attention ought to be on the actual appropriation activity of EV and not simply on the intercession. Besides, the hole between goal and conduct is essential to consider. Shopper information and abilities for assessing and contrasting the monetary advantage and cost of EV are the significant examination hole of the flow research. Future investigations on the best way to advise clients may have suggestions for knowing the monetary advantage and cost of EV's by strategy creators and promoting subject matter experts.

2 Relevance

In this section, the authors want to discuss few key factors related to the subject. Before understanding the concept of the subject, it is always good to know the basic terms or elements.

2.1 Electric Vehicle

An electric vehicle, likewise called an electric drive vehicle, utilizes at least one electric engine or footing engine for impetus. An electric vehicle might be controlled through a gatherer framework by power from off-vehicle sources or might act naturally contained with a battery, sun-oriented boards, or an electric generator to change fuel over to power. EVs include road and rail vehicles, surface and sunken ships, electric airplanes, and electric space equipment. EVs originally appeared during the nineteenth century, when power was among the favored techniques for engine vehicle drive, giving a degree of solace and simplicity of activity that couldn't be accomplished by the fuel vehicles of the time. Present-day inward burning motors have been the predominant drive strategy for engine vehicles for just about 100 years, yet electric force has stayed typical in other vehicle types, like trains and more modest vehicles, all things considered. In the 21st century, EVs saw resurgence because of innovative turns of events and an expanded spotlight on environmentally friendly power. Government impetuses to build receptions were presented, remembering for the United States and the European Union [1].

***Table 1**: Specifications of E-Bike in Various Countries*

Country	Types of Bike	Speed limit in km/hr.	Watt	Weight in Kg	Minimum Age Requirement
Australia	Pedal	25	250	NA	None
Canada	Hand	32	500	NA	Varies
China	P/H	30	200	20	None
Norway	Pedal	25	250	NA	None
Israel	Pedal	25	250	30	14
UK	Hand	27	250	40	14
Taiwan	Hand	25	200	NA	None
US	Hand	25	750	NA	None
China	P/H	30	500	NA	None

Courtesy 1: (Shinde, 2017)

2.2 Hybrid Vehicle

A hybrid vehicle is any vehicle that uses two or more fuels to run successfully. Let us consider the example

Proceedings DOI: 10.21467/proceedings.118
ISBN: 978-81-947843-6-4

Series: AIJR Proceedings
ISSN: 2582-3922

of a submarine. The submarine uses diesel when the water floats to the surface. And the submarine uses the submerged battery energy as fuel. Instead, there are many types of hybrid vehicles available. However, we only know of a few common types of hybrid automobiles.

2.3 Stirling Engine

A Stirling engine is a heat engine that operates at different temperatures through cyclic compression and expansion of air or other gases (working liquids), such as the transformation of heat energy into mechanical work. A sterling engine is a heat engine that operates at different temperatures through cyclic compression and expansion of air or other gases (working liquids), such as the transformation of heat energy into mechanical work. More specifically, the Sterling engine is a closed-cycle regenerative heat engine with a permanently aerated working fluid. More specifically, the Sterling engine is a closed-cycle regenerative heat engine with a permanently aerated working fluid. The close-cycle, in this context, is a thermodynamic system in which the working fluid is permanent in the system, and the regenerator describes the use of a specific type of internal heat exchanger and thermal store, known as regeneration. Strictly speaking, the inclusion of a regenerator means that the stealing engine is distinguished from other closed cycle hot air engines. Originally conceived as a prime mover to compete with a steam engine, its practical use has been largely limited to low-energy home applications for centuries.

2.4 Alternator

Rising power demand in automotive applications led to the development of a three-phase alternator that surpassed DC generators. The automotive DC generator lacks zero output at idle and requires maintenance as the entire electrical output goes through the commuter. The development of semiconductor diodes means that the alternating current of AC machines can be reliably repaired on solid-state diode bridges by providing cheap production of compact and reliable three-phase alternators

3 Literature Survey

Doucette and McCulloch (2011) have explored the positive effects of electric vehicles on the environment. According to the author, electric vehicles may be a viable option for petroleum vehicles. The authors also included the government's approach to the implementation of electric vehicles. They also discussed sustainable approaches. Authors also have focused on the various benefits of electric vehicles; such as minimization of the use of petroleum products, minimizing the use of fossil fuels for power generation, etc. [2].

Shete Y. S. (2019) However, the utilization of EVs has started, individuals are as yet relying on non-renewable energy source fueled vehicles. In any case, the EVs are confronting difficulties on life cycle evaluation (LCA), charging, and driving reach contrasted with the customary fossil-powered vehicles. The CO_2 radiated from Electric vehicle creation is (59%) more than that of the ICEV. The ICEV creates 120 g/km of CO2 emission on a tank-to-wheel premise, yet according to the perspective of the LCA, this increments to 170–180 g/km. However, EVs have zero emissions of CO2 on a tank-to-wheel infrastructure. In addition, the authors hypothesized that CO2 has predicted an existing vehicle pattern rather than a regular vehicle [3].

Climatelinks, (2019) In 2014, India's general ozone-depleting substance emission added up to 3202 million metric huge loads of carbon dioxide same, which represented 6.55% of worldwide ozone-depleting substance emissions. In India, 68% of ozone-harming substance emissions come from the energy area, trailed by horticulture, producing measures, upgrades in land use and ranger service, and waste adding 19.6%, 6.0%, 3.8%, and 1.9% comparative with ozone-depleting substance emission [4].

Wolfram & Lutsey, (2016) discovered that, it founds that fossil fuel byproducts of BEVs utilizing European matrix blend power are about the portion of general European vehicle emanations, though HFCEVs and PHEVs have lower outflows decrease potential. In the year 2020, because of more proficient force prepares and expanding low-carbon electric force, the electric vehicle WTW outflows are required to keep offering more noteworthy carbon benefits. A lower-carbon network and higher force train effectiveness by 2020 could cut regular electric vehicle outflows by 33% once more. In any case, the regular expense decreases, and potential CO2 discharge cuts won't be accomplished without a designated strategy intercession. More tough CO2 norms and monetary and non-monetary impetuses for electric vehicles can help the electric vehicle market to develop and expenses to fall. Too, endeavors should be joined with exercises to decarbonize the framework or outflow decreases won't be pretty much as extraordinary as they could be. Albeit the investigation is centered on the European setting, comparative elements with electric vehicle innovation, strategy, and market improvement are common across major markets in North America and Asia [5].

Wolfram and Lutsey (2016) they have expressed about battery charging, there are three sorts of charging frameworks for BEVs and PHEVs. Level 1 charging focuses give alternative current capacity to the vehicle through a standard low-power 110-volt circuit, like those utilized in families in the United States or Japan. With this sluggish charging focus, a 24 kWh battery requires more than 20 hours of charging to get fully charge. Private or public Level 2 charging focuses in the United States give substitute current force through a 240 volt (and 30 amp) circuit, also, would thus be able to cut charging time by about half. Level 2 charging through a 230 volt (and 15 amps) outlet is regular in families in the EU and most different nations. Electrical board redesigns are fundamental in the United States to reach a similar voltage. Level 3 charging focuses convert alternating current line voltage to a high-voltage, direct current. If stopped at a fast-charging point, the charging of the battery can reach up to 80% (which is the highest level suggested) in 30 minutes. In any case, the venture cost of Level 3 chargers is a lot higher than those for Level 1 and 2 [5].

Shete et al. (2018) The Series Hybrid Electrical Petroleum Cycle Framework is a type of framework in which a bike works using a motorcycle until the battery gets discharged and then when the generator starts charging the battery and to keeps the vehicle running while the work is in progress. This vehicle is almost an electric vehicle that has a module that facilitates battery charging with the inventory. This might be called a Plugin half-breed electric vehicle (PHEV). These comprise the batteries having broadened limits. PHEV operates using batteries not only during the entire journey but at the end of the trip it goes to the engine. This transfer is intentional and done to reduce the possibility of overcharging the battery. PHEV requires a limited amount of mechanical linking, so the system is simple and Easy. Fundamentally PHEV requires fewer mechanical linkages, so the framework turns out to be simple and basic [6].

Belekar et al. (2017) have expressed that the skeleton of an economically accessible bike is altered according to the prerequisites of the battery sizes and oneself charging framework. The parts like alternator, engine and DC-DC converter were masterminded in a way to move the rotational energy being capable by the chain sprockets through the chain to the alternator. The alternator here can create 14.4V DC, which is coordinated to a DC-DC converter through a battery source. Here in the DC-DC converter, the voltage source is ventured up to 54V, which is sufficient to charge the 4 batteries in series which respects 48V use. Consequently, the utilization of batteries to give the rotational energy to the shaft through an engine is getting back the sufficient voltage source to re-energize it. The vehicle is tried for the stock of source to the batteries utilizing multi-meter, distance went with and without the re-energizing circuit is likewise examined and is discovered to be compelling [7].

Proceedings DOI: 10.21467/proceedings.118
ISBN: 978-81-947843-6-4

Series: AIJR Proceedings
ISSN: 2582-3922

4 Methodology

4.1 Problem Statement

In general, electric vehicles are classified as plugs in hybrid electric vehicles (PHEVs). Such vehicles require a plug-in to charge. It needs a power supply for a purpose to charge the battery. Considering India's infrastructure for electric vehicles, India fails to provide such facilities across the country. Everyone cannot find such electric sources where they are needed. In addition, an analysis of the best electric bikes in India has found that these bikes can travel around 70 to 80 kilometres per charge. So, it took 6 to 8 hours to fully charge the battery [8].

4.2 Concept

Here similar technology used in the Series hybrid Electric Petroleum Bicycle is going to be used [6]. This type of vehicle initially generates electricity using an engine. This power is used to drive a vehicle. Also, this power is used by the alternator to charge the battery. In this type of vehicle we will use the Sterling engine for initial power generation as well as for charging the vehicle. The power control unit on the other hand splits the power to charge the battery when the bicycle runs on the energy generated by the Sterling engine. When the battery is fully charged, the power control unit will signal the indicator, and then the engine should be disconnected. The vehicle runs on battery and BLDC after the engine is cut off.

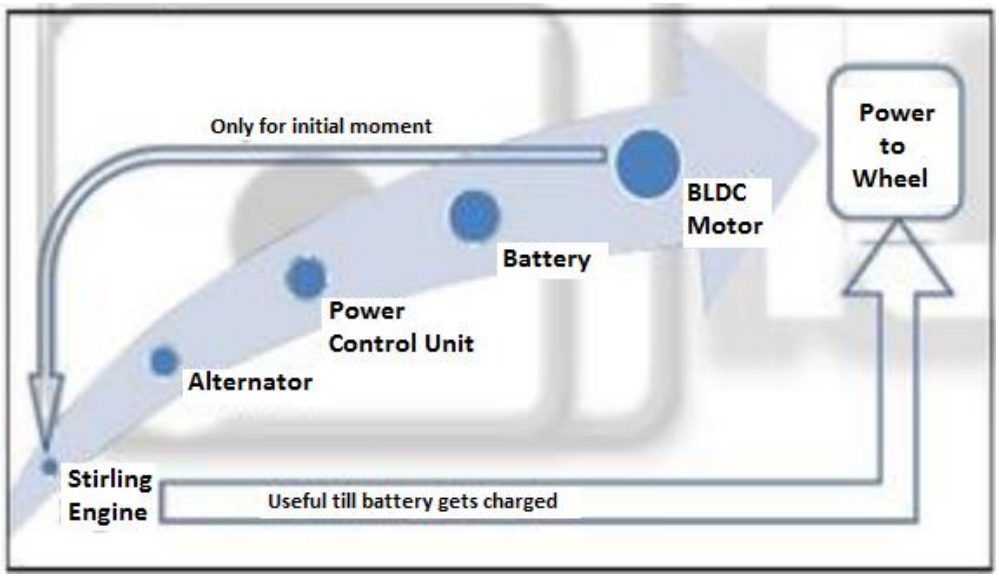

Figure 1*: Concept for Stirling based Hybrid Bicycle*

Concept of Stirling Engine Based Battery Charging System:

In a battery charging system based on the Stirling engine, the Stirling acts as a prime mover that is connected to an alternator with the help of a mechanical drive. It also makes an alternator shaft to rotate whenever the Stirling engine starts working. This rotation of the alternator generates electrical power. This generated electromotive power is being stored in the battery by an electric circuit [9].

4.3 Working Principle

This Stirling based hybrid electric bicycle works on the principle used in Toyota drive. So some changes have been made according to the needs of the bike. There are basically four ways this bike works. Let's discuss each topic in detail. Whereas, in addition to these four major stages, alternator battery charging system and Stirling based charging system are also included in this bicycle.

Starting Off

Figure 2: *Power Management System for Starting Off*

At this stage, high power is required to start and drive the vehicle. For the same purpose, a power control unit with an electronic device operates in such a way that power is received from main source that is battery. During this step, battery discharging occurs.

Acceleration

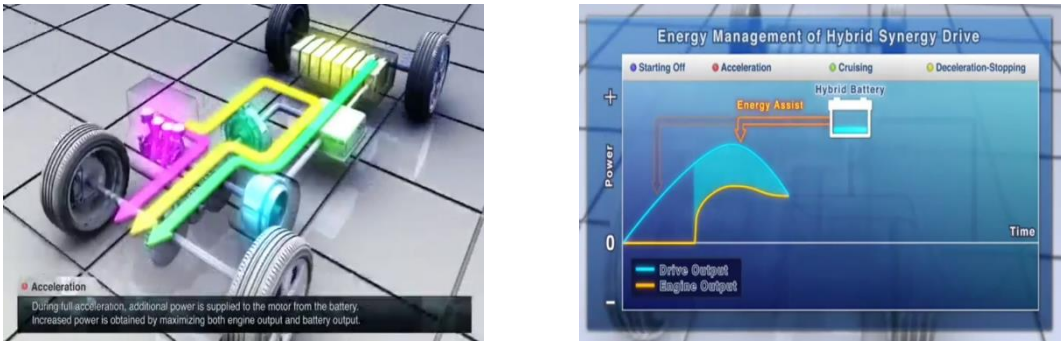

Figure 3: *Power Management System for Accelerating*

During acceleration, there is also high power requirement till vehicle did not get suitable power to maintain stable working of the vehicle. Acceleration requires highest power, therefore the power get provided by all available sources for vehicle such as engine, battery, generator, and regenerative system. During this stage, the discharging of battery occurs.

Cruising

Once accelerated and reaches sufficient speed, the phase occurs as cruising. This is nothing but a constant speed phenomenon. According to the study, any vehicle running at a constant speed consumes the least amount of fuel, so at this point, the power control unit turned off the battery and the vehicle started using only the engine. So, the power control unit manages to charge the battery with the help of regenerator at this stage.

Proceedings DOI: 10.21467/proceedings.118
ISBN: 978-81-947843-6-4

Series: AIJR Proceedings
ISSN: 2582-3922

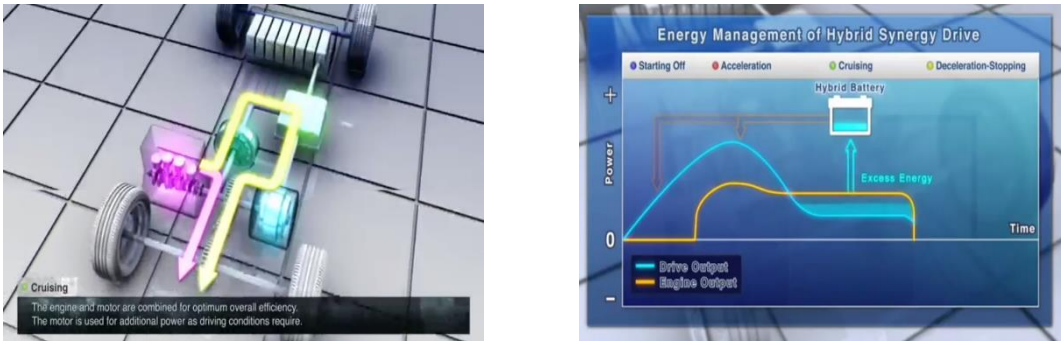

Figure 4*: Energy Management at Cruising*

Regenerative Braking/ Deceleration

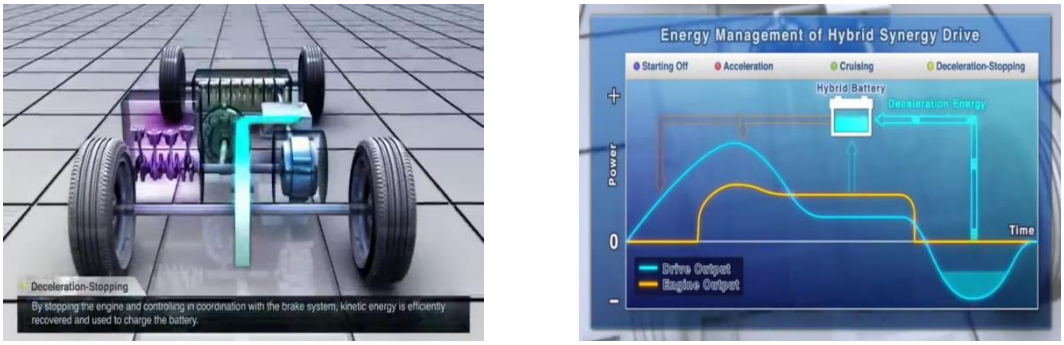

Figure 5: *Energy Management during Deceleration*

Deceleration is the process of applying the brakes or lowering the vehicle. But there is no need to use force for the same purpose. On the other hand it helps in power generation while the work is slow. This process is called regenerative braking system. As shown in the figure, the battery is charging.

Battery Charging using Stirling Engine using Alternator

This is a much simpler system. In this system, a simple mechanical drive is used to transmit power from the engine to the alternator. Drive is nothing but belt drive. The V belt is most suitable for transmitting energy from the Sterling engine to the alternator. In addition the alternator is also connected to the wheels. This will cause constant rotation of the alternator shaft. The charge output of the alternator for charging charges and driving is connected to electronic circuits with different sensors and microcontrollers. Following figure shows different components of the system.

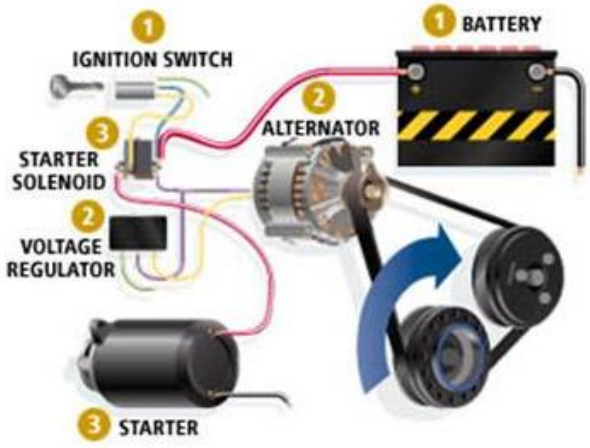

Figure 6: *Alternator Battery Charging System*

5 Results and Discussion

Many tests have been performed on the developed model. In this chapter, the author only discusses energy utility testing against the motion. Wind resistance and resistance have been ignored to analyze these test results. In addition, comparisons between electric and Stirling-based hybrid cycles are also discussed.

5.1 Speed vs. Power Requirement test for Electric Bikes

At Load of approx. 50 kg. (Rider Only)

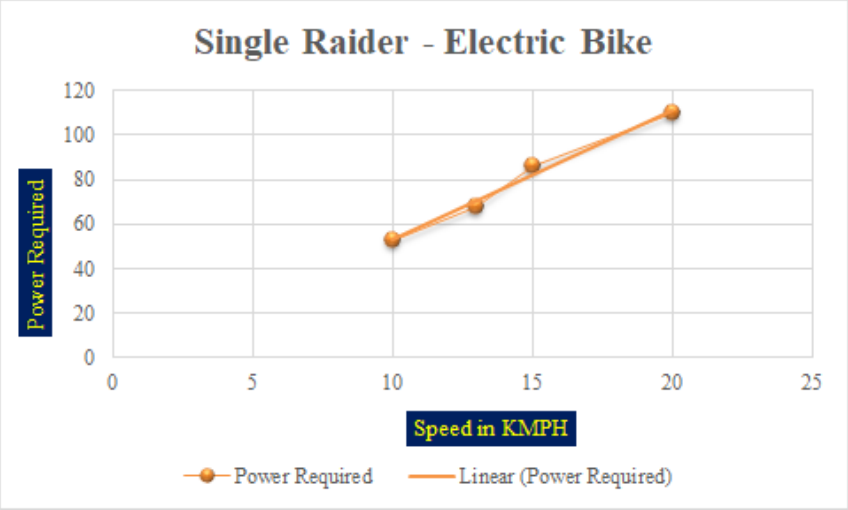

Figure 7: *Power vs Speed characteristic curve for Electric Bike for Rider only*

The current test runs at a load of approximately 50 kg. This is for rider only. The above curves clearly indicate that the power required to increase the speed, increases accordingly. Also the obtained curve is around the linear features of the respective matter. It found, there is very little difference between the linear curve and the values obtained. Where recorded values were taken without considering resistances such as wind and resistive traction.

At Load of approximate 120 Kg (Rider + Passenger)

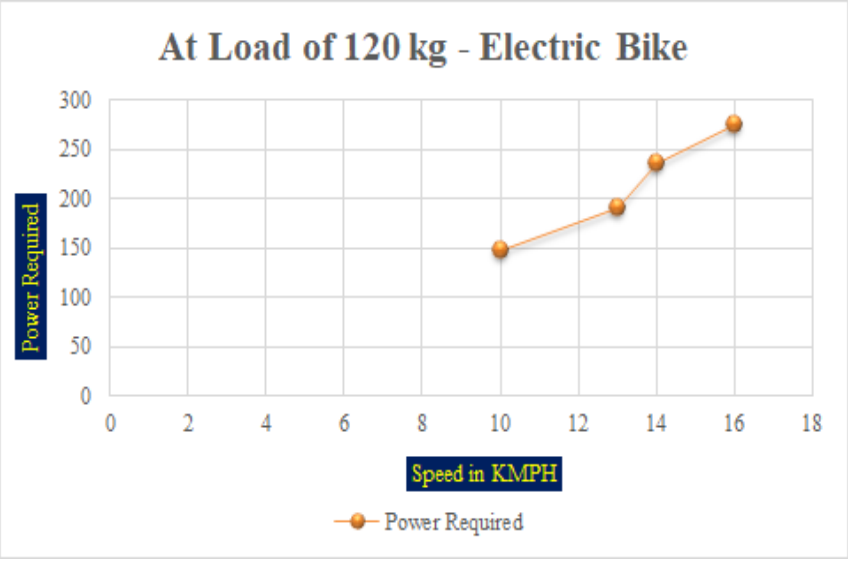

Figure 8: *Power vs Speed Characteristic Curve for Electric Bike at Load of 120 Kg approx.*

Proceedings DOI: 10.21467/proceedings.118
ISBN: 978-81-947843-6-4

Series: AIJR Proceedings
ISSN: 2582-3922

The next test of the electric bike took place. Now the bike is loaded with about 120 kg. The above curve shows the deviation in the values obtained compared to the linear characteristics. It can be concluded that if there is too much load, unstable relationships for power and speed can arise.

5.2 Speed vs. Power Requirement test for Stirling Based Hybrid Electric Bikes

Since the hybrid bike runs on both electric as well as engine power during peak load [6], it can get higher speeds and the increase is relative energy production. Therefore the values obtained for this particular model are different from the values obtained by electric bikes.

Speed vs. Power test for Rider only

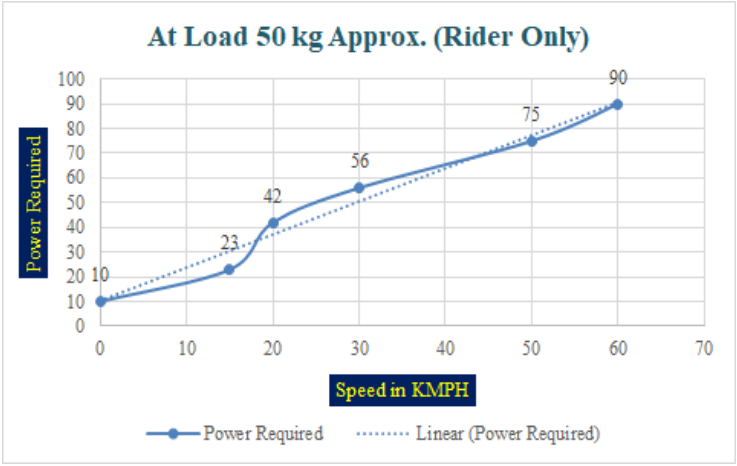

Figure 9: *Power vs. Speed Characteristic Curve for Hybrid Electric Bicycle at plane Surface*

As already discussed, the energy gained by a hybrid bike is higher than that of an electric bike. The speed has also improved for hybrid bikes. The graph obtained by analysing the values of the hybrid cycle shows that initially the rate increase was achieved with the required force, but after that, the graph shows the linear charactristics.

At Load of approximate 120 Kg (Rider + Passenger)

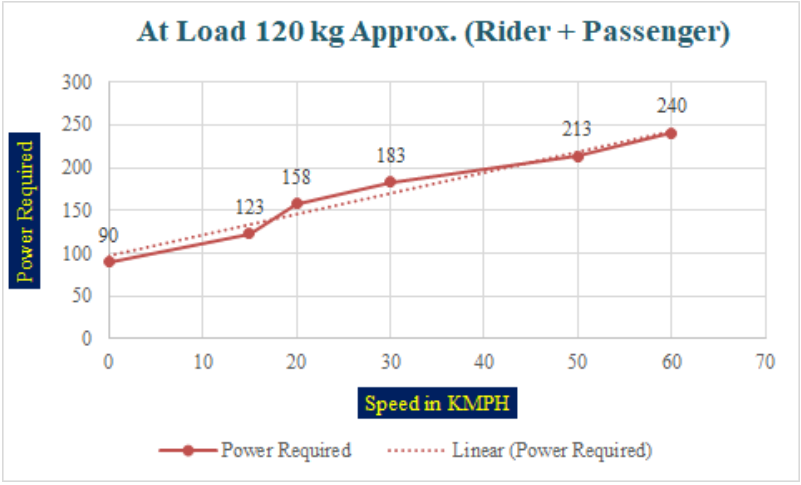

Figure 10: *At Load of approximate 120 Kg (Rider + Passenger)*

This test is carried out at a load of about 120 kg. The above curve shows the linear characteristics as well as the increase in energy required in relation to the load to achieve the desired speed. There is not much deflection available in the values obtained according to the linear curve.

6 Conclusions

The described model is designed to improve performance in electric bike. However, as already discussed in the results, comparisons between electric bikes and developed hybrid bicycles show a significant increase in power development as well as the speed achieved by bikes. The characteristic curves are about the linear characteristics of both electric as well as hybrid bikes. The main difference between these two bikes is their ability to carry loads with dedicated power. The hybrid drive system uses both electrical as well as mechanical power to operate. There is also a difference between the batteries used for hybrid and electric bikes. This was done on basis of the capacity and quality of the charge required for each. Here, in the results even when there is no charging or discharging curve. This is because the discharging of the battery is inversely proportional to the electrical energy requirement. The higher the power required, the more the battery must be discharged, but in the case of hybrid electric bikes, higher speeds of vehicles can cause a higher revolution of the alternator shaft. The result is an increase in the current generation through alternators. It generates successful charging of batteries through current electronic circuits and power control units.

In addition to performance, the Stirling engine is blown from the outside into the hot air engine, no specific fuel is required to heat the air. We can use any burner to heat the hot cylinder. The use of solar heaters or electric heaters can also be useful for providing heat. Therefore, emissions can cause very little or no pollution. In addition, the noise level is also on par with electric bikes.

7 Declarations

7.1 Acknowledgements

I like to present my gratitude towards Prof Pawar S. A., project guide and HOD of the Mechanical Department, FTC, COER, Sangola. He constantly urged me to do such things. He has added his valuable guidelines for the success of this project. Also, I am very thankful to other staff and the Principal for providing me such an excellent opportunity. Last but not least, my kind gratitude towards the chairman of RST Pvt Ltd for approving my application and providing me an opportunity to work in the industrial environment.

7.2 Study Limitations

The developed system is just a model of study. There is a possibility of the addition of other accessories to the overall structure. Effective use of the gearbox is also possible. It is possible to implement a different engine and firing technique for this project. The author wants to announce that this model is an addition to the electric bike to overcome issues related to charging and the shortage of electricity. Total equipment and engines are additional components to the electric bike. Another goal is to increase the speed of electric bikes. There are numerous factors available, which may affect the performance of this particular derived model. In actual practice, the generation of a model for study purposes only. There may be a lack of different standard accessories and facilities that affect performance ratings. Environmental factors such as absolute temperature, air pressure, and humidity in nature can affect the generation of a Stirling Engine as well as the ability of a battery to hold a charge. Changes in battery type also affect the overall performance of the hybrid cycle. In addition, using any other rated motors and equipment may also differ in the results obtained by this model and the overall results. There is great scope for further research and development for this particular system.

7.3 Funding Source

The author is very grateful to "Renuka Services and Technology Pvt Ltd." a private company that approved the sponsorship application. The company provided funds as well as added valuable guidance for the successful development of the project.

References

[1] K. Shinde, "Literature Review on Electric Bike," *InternatIonal Journal of Research In MechanIcal EngIneerIng & Technology*, vol. 7, no. 1, pp. 73-77, April 2017.

[2] R. Doucette and M. McCulloch, "Modeling the prospects of plug-in hybrid electric vehicles to reduce CO2 emissions," *Applied Energy*, vol. 88, no. 7, pp. 2315-2323, July 2011.

[3] Y. S. Shete, "Engine Emission and Their Control: Review," *International Research Journal of Engineering and Technology*, vol. 06, no. 01, pp. 450-456, 01 January 2019.

[4] Climatelinks, "Greenhouse Gas Emissions Factsheet: India," 31 January 2019. [Online]. Available: https://www.climatelinks.org/resources/greenhouse-gas-emissions-factsheet-india. [Accessed 07 July 2021].

[5] P. Wolfram and N. P. Lutsey, "Electric vehicles: Literature review of technology costs and carbon emissions," *International Council On Clean Transportation*, pp. 01-23, July 2016.

[6] Y. S. Shete, V. R. Londhe, Y. J. Bhosale and A. I. Mujawar, "Study, Development & Modificationsof Series Hybrid Electro-Petroleum Bicycle," *International Research Journal of Engineering and Technology*, vol. 5, no. 3, pp. 2385-2388, 01 March 2018.

[7] R. D. Belekar, S. Subramanian, P. V. Panvalkar, M. Desai and R. Patole, "Alternator Charging System for Electric Motorcycles," *International Research Journal of Engineering and Technology*, vol. 4, no. 4, pp. 1759-1766, 1 April 2017.

[8] Y. S. Shete, "Development of Hybrid Bicycle using Stirling Engine: Concept," *International Journal For Scientific Research & Development*, vol. 08, no. 02, pp. 116-118, 01 May 2020.

[9] S. Goel, R. Sharma and A. K. Rathore, "A review on barrier and challenges of electric vehicle in India and vehicle to grid optimisation," *Transportation Engineering*, vol. 4, p. 100057, June 2021.

[10] A. Muetze and Y. Tan, "Electric bicycles - A performance evaluation," *IEEE Industry Applications Magazine*, vol. 13, no. 04, pp. 12-21, August 2007.