Hybrid human powered vehicle: Research area of electric bicycles.

N.T.Kurhe*, V.D.Wakchaure, Umesh Gurnani*, and Anurag Hamilton***

**University of Engineering & Management Jaipur INDIA.*
***Amrutvahini College of Engineering Sangamner MH, INDIA.*
navnath.kurhe3@gmail.com, wvishnu@rediffmail.com, umesh.gurnani@uem.edu.in, anurag.hamilton@uem.edu.in

Abstract

Increasing internal combustion propelled vehicles in urban and rural areas has given rise to many adverse effects such as emissions of harmful pollutants like hydrocarbons, nitrogen oxides, carbon monoxide and particulate matter which directly or indirectly affects human health. A busy lifestyle and less exercise can lead to physical problems. To reduce use of fossil fuel and health related problems Human powered vehicles are one of the practical possibilities for sustainable transport systems. The vehicle which is driven by human power i.e. muscular power will provide an immediate solution to fuel limitations and pollution caused by conventional fuel propelled vehicles. Although much research has been done on electric bicycles, more research is needed on speed, power sources, batteries, charging methods, bicycling facilities/infrastructures, rider comfort, and safety. This paper focuses on the improvements needed in the field of electric bicycles such as energy sources, Electric motors, Control method, Transmission, Charging methods, Safety, infrastructures and ergonomics etc.

Keywords: Human powered vehicle (HPV), Electric vehicles(EVs), Electric Bicycle(EBs), Effortless bicycle, sustainable mobility; future mobility etc.

1. Introduction

Environmental pollution is a big issue caused by exhaust emissions of fossil-fueled internal combustion vehicles. Many countries are planning to reduce use of petrol and diesel vehicles. All over the world research is going on to reduce environmental pollution caused by the automobile sector. Electric vehicles are the best solution to reduce environmental pollution but still many power plants which are using coal as fuels lead to pollution. There will be a large number of electric vehicles in the future. The electric vehicle is still in the developing stage, Cost of the electric vehicle is still high and its range is less. It is necessary to develop such a type of transportation system which should be affordable, environmentally friendly and safe. Electric bicycles are environmentally-friendly, having zero-emission and many benefits among electric vehicles. Electric bicycles cost less; require less maintenance and also health related benefits. The use of electric bicycles is encouraged in most countries. Separate infrastructure has also been

created for this. Due to the health of citizens, zero emission environment friendly electric bicycles do not require licenses and taxes in most of the countries. Electric bicycles are generally classified into pure e-bicycles, power-assisted electric bicycles and combine mode. Electric motors used to drive the wheel of electric bicycles. Speed of an electric bicycle is controlled by controlling electric currents through a handlebar throttle. The pure EBs may be used as a hub motor or in some cases a motor installed on the frame and power is transmitted to the wheel through the drive mechanism. The use of electric motors in power assisted cycling helps the rider to cycle. This means the driver can cycle in low power. In combine mode electric motors and muscle power are used together. In pure mode only electric motors are used and in power assisted mode driver and motor power are used. Much research is still being done to improve performance of electric bicycles. In order to provide research of EBs, this review paper presents development needed in the field of electric bicycles.

2. Energy sources of electric bicycles.

The muscular power, electric battery and solar energy are the energy sources of an EBs. Solar energy is still in the developing stage and it is having great exposure in the field of EBs. The most widely used energy source in electric bicycles is the battery. Battery is the heart of electric bicycles and its important properties include high energy density, fast charging, light weight, long lifespan, discharging, safety, recycling, Eco-friendliness and low cost. The patent of a zinc-carbon battery filed by Hosea W. Libbey which was then used for the EB in 1897 [4]. Lead-acid battery, Nickel-metal hydride battery, Nickel-cadmium battery, Lithium-ion battery, and Lithium-ion polymer battery were commonly used in electric bicycle and still having research exposure in storage capacities, charging and discharging rate, weight reduction, life of battery and safety. Other power sources like fuel cells, zinc batteries and sodium batteries can be used for EBs. Fuel cell efficiency is high, so researchers are focusing more on this. Due to the use of fuel cells it can cause more travel in a single charge. Hydrogen is expensive, it is explosive and difficult to store. Using it in the electric cycle can be challenging for researchers [1].

3. Electric motors

Electric motors on EB are generally classified into brushed DC and brushless DC (BLDC). Brushed DC motors are cheaper and stronger but they are heavier and noisier. In addition, they need frequent maintenance. Compared to DC motors, BLDC motors are lighter in weight, less noisy and have less maintenance. According to the location of motors, electric motors are classified into rear wheel hub motors, front wheel hub motors and in a mid-drive position. Researchers have challenges while developing motors like speed, torque, wheel slippage and uniform weight distribution for smooth function of EBs [1].

4. Control method.

EB's performance is improving due to electric motors and its control methods. Most of scientists presented research studies on operating performance of EBs. Their research helps to investigate the dynamic characteristics and optimize the power requirement of an electric bicycle. They have used different controlling systems such as PI, PID, Fuzzy PID, Hybrid Fuzzy and NMPC for effective and smooth functioning of EBs. Effective control of solar batteries and pedaling forces is a challenge for researchers as the smooth and effective function of EBs [1].

5. Transmission

The transmission system is a basic system that affects the dynamics performance of the electric bicycle. The EBs transmission systems provide different outputs for the input of the gearbox. As per the design requirement location of the gearbox varies and it can affect the performance. Hung and his team presented an experiment and simulation on the operating performance of a semi-automatic transmission system of EBs [2]. Abagnale et al. showed the motion transmission for the simple bevel gear and planetary gearbox and[5].Wu and Sun designed and developed speed-wheel hub motors which made transmission systems more compact[6]. Transmission systems play an important role in EBs and still have their challenges for speed and torque of EBs.

6. Charging methods and charging stations.

Good charging methods and charging stations will promote the use of EBs in the future. The constant current [7] and constant voltage [8] are the charging methods of EBs. Later on, a combination of constant current and constant voltage came to charge the EBs. The overheating problem and charging time reduced, also improved the life of the battery [9]. The charging method of EBs is also classified into plugged in and wireless charging. Inductive power transfer systems are used in the Wireless charging methods [10]. Wireless charging is safer because of no physical contact. It is maintenance-free and unaffected by any type of chemicals, water and dirt. Availability of charging stations along with suitable charging methods will contribute to the EBs market.

7. Cost of Electric bicycle

Battery, electric motors, electronic control units and other accessories increase the cost of electric bicycles. Cost of the battery is more and the range of an electric bicycle battery is up to 25 to 30km. Average time is 4 to 5 hr. required for charging and the battery can be charged up to 1000 cycles. The running cost of electric bicycles is less but because of limited battery life leads to increase in the maintenance cost. Research work is necessary in optimization of design, performance of battery, effectiveness of motor and control systems which will affect the cost of EBs [1].

8. Bicycle aerodynamics and ergonomics, Infrastructure

After realizing that wind is an important source of cycling resistance, aerodynamics and driver position were used in cycling. Fabio Malizia presented a review paper in which he elaborated the components of bicycle and its speed performance according to the ergonomics [17]. He also focused on his next studies cycling flows, cyclist wearing components and aerodynamic interaction [19].Shih-Wen Hsiao presented concept “fitting object to the human body”. In which he designed bicycle frames and proposed a table of frame size for common bicycles [20].V. Balasubramanian presented his studies about the investigation of muscle activity during cycling. In which he experimented on different bicycles and he came to the conclusion that suspension cycling feels more relaxed as compared to rigid and sport bicycles [21]. Hongliang Ding et al. presented study on cycle path for safety of bicycle and his study is useful for bicycle infrastructures which improve the bicycle safety and reduce accident.[11]. Rider safety and Development of infrastructure is the most challenging field in development of high speed electric bicycles.[11-16]. Redesigning electric bicycles is necessary to avoid rider fatigue and it will provide more safety along with driver comfort. In the EBs, the main resistance is wind and the main challenges of researchers to develop bicycles which will reduce it.

9. Conclusion

Due to the many advantages of electric bicycles, there may be huge demand in the future. These research areas can be useful for manufacturers and researchers for the development of electric bicycles. These research fields could be providing good references for readers, manufacturers and researchers to develop their electric bicycles according to the research ideas. EBs have many challenges such as safety and rider comfort during riding, battery range, infrastructure which include charging station and battery recycling. Battery waste is going to be one of the biggest environmental challenges of the future. Although electric bicycles are environmentally friendly and useful for health, research in torque, batteries, ergonomics, bicycle infrastructure and aerodynamics will be important for the electric bicycle market.

References

[1] Nguyen Ba Hunga,b, Ocktaeck Lima, 2020. A review of history, development, design and research of electric bicycles. Applied Energy 260:1-18.

[2] Hung NB, Sung J, Lim O. A simulation and experimental study of operating performance of an electric bicycle integrated with a semi-automatic transmission. Appl Energy 2018;221:319–33.

[3] US536689. Electric battery; 1895.

[4] Morchin WC, Oman H. Electric Bicycles – A Guide to Design and Use. Wiley-IEEE Press; 2006.

[5] Abagnale C, Cardone M, Iodice P, Strano S, Terzo M, Vorraro G. Model-based control for an innovative power-assisted bicycle. In: 69th Conference of the Italian Thermal Machines Engineering Association; 2014.

[6] Wu YC, Sun ZH. Design and analysis of a novel speed-changing wheel hub with an integrated electric motor for electric bicycles. Math Probl Eng 2013;2013:1–8.
[7] Adhisuwignjo S, Siradjuddin I, Rifa'i M, Putri R.I. Development of a solar-powered electric bicycle in bike sharing transportation system. IOP Conference Series: Earth and Environmental Science 2017;70:1–10.
[8] Panicker BM, Sajeev AP, Akhil P, Babu AR, Arjun KU, Varghese N. Electric bicycle with three way charging. Int J Adv Res Electr Electron Instrum Eng 2016;5:2833–8.
[9] Garcia-Valle R, Peças Lopes J.A. Electric Vehicle Integration into Modern Power Networks (Power Electronics and Power System). Springer; 2012.
[10] Beh HZ, Covic GA, Boys JT. Investigation of magnetic couplers in bicycle kickstands for wireless charging of electric bicycles. IEEE J Emerg Select Top Power Electron 2015;3:87–100.
[11] Hongliang Ding. Role of exposure in bicycle safety analysis: Effect of cycle path choice, Accident Analysis and Prevention, 2021:1-11
[12] Anne Vingaard Olesen, Single-bicycle crashes: An in-depth analysis of self-reported crashes and estimation of attributable hospital cost, Accident Analysis and Prevention 2021:1-12
[13] Brian CaseyLangford, Single-bicycle crashes: An in-depth analysis of self-reported crashes and estimation of attributable hospital cost, Accident Analysis & Prevention,2015: Pages 220-226
[14] Martin Hallberg, Modelling the impact of cycle superhighways and electric bicycles, Transportation Research Part A: Policy and Practice, 202:397-418
[15] LarsLeden, Bicycle Collision Avoidance Systems: Can Cyclist Safety be Improved with Intelligent Transport Systems?, International Encyclopedia of Transportation,2021: 108-114
[16] Lorenzo Stilo, Electric bicycles, next generation low carbon transport systems: A survey, Transportation Research Interdisciplinary Perspectives,2021:1-13
[17] FabioMalizia, Bicycle aerodynamics: History, state-of-the-art and future perspectives, Journal of Wind Engineering and Industrial Aerodynamics,2020
[18] Harun Chowdhury, A full scale bicycle aerodynamics testing methodology, Procedia Engineering 13 (2011) 94–99
[19] FabioMalizia, Cyclist aerodynamics through time: Better, faster, stronger, Journal of Wind Engineering and Industrial Aerodynamics,2021:1-33
[20] Shih-WenHsiao, Applying riding-posture optimization on bicycle frame design, Applied Ergonomics, 2015:69-79
[21] Pielecha J, Merkisz J, Jasinski R, Gis W. Real driving emissions testing of vehicles powered by compressed natural gas. SAE Technical Paper, 2015-01-2022; 2015.