ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

IARJSET

International Advanced Research Journal in Science, Engineering and Technology

AGNI-PANKH 16

Jawaharlal Darda Institute of Engineering and Technology, Yavatmal

Vol. 4, Special Issue 3, January 2017

Performance Evaluation of Electric Bicycles

Akshay N. Khonde[1], Aditya R. Ughade[2], Kapil D. Warghane[3], Rajat R. Vidhale[4]

Students, Department of Mechanical Engineering, JDIET, Yavatmal, India [1, 2, 3, 4]

Abstract: This paper addressees a systematic, comprehensive classification of electric bicycles that includes an overview of the state of the art of today's commercially available electric bicycles. The overview includes less commonly considered topics, such as regulatory issues in various countries, and different performance requirements of electric bicycles.231 have been making their way into the U.S. market for about two decades.231In this paper, the term "electric bicycle" is used to describe "electric-motor-powered bicycles," including both fully and partially motor-powered bicycles. Electric bicycles can be used for a variety of purposes, for instance, as a vehicle for police or law enforcement in cities where parking and traffic are a problem, as a guide bicycle during bicycle races, as a park ranger vehicle, or for leisurely rides and commuting purposes. The paper then gives a summary of the different results that can serve as a roadmap for such improvements. This summary includes both market trends and regulations and technical-science-related aspects. Different paths of further research to build on the presented work are outlined in the conclusion.

Keywords: electric-motor-powered bicycles, direct current (DC), hub motor, gears.

I. INTRODUCTION

Electric bicycle is a bicycle with an electric motor attached to the rear wheel of the bike which generally assists the rider while he or she is peddling. Usually, electric bicycles get their power to drive and run the electric motor from energy stored in electric batteries that are located somewhere within the electric bicycle. These batteries are usually rechargeable by plugging them into a regular household outlet and the batteries are usually stored in a charger when doing so.

Sometime around the year 1898, electric bicycles were documented within various U.S. patents. On 31 December 1895, Ogden Bolton Jr. was granted U.S. Patent 552,271 for a battery-powered bicycle with a 6-pole brush and commutator direct current (DC) hub motor mounted in the rear wheel, there were no gears and the motor could draw up to 100 amperes from a 10-volt battery. One of the first rear wheel electric drive was implemented by using a belt along the outside of the bike. It wasn't much longer than that in which other improvements were made to the electric motor itself which proved significant.

II. BASIC CONFIGERATION AND OVERVIEW OF ELECTRIC BICYCLES

The basic configuration of an electric bicycle drive consists of a controller that controls the power flow from the battery to the electric motor. This power flow acts in parallel with the power delivered by the rider via the pedal of the bike. The rider of an E-bike can choose to 1. Rely on the motor completely 2. Pedal and use the motor at the same time 3. Pedal only (use as a conventional bicycle).

Electric bicycles have been gaining increasing attention worldwide, especially in China, Europe, Japan, Taiwan, and the United States. In the following, the most distinguishing aspects of electric bicycles in these countries are summarized, based on the authors' own studies and Frank Jameson's Electric Bikes Worldwide 2002 [1]. Today, China is the largest manufacturer of electric bicycles, exporting the majority of the electric bicycles while also meeting a strong local demand. According to China's Electric Bike General Technical Qualification GB17761-1999 [9], Chinese electric bicycles may not exceed 20 km/h and may not be heavier than 40 kg. In Europe, most electric bicycles are manufactured in Germany and the Netherlands, and pedelec-type electric bicycles are more common.

In Japan, most electric bicycles are produced by the automotive industry, and electric bicycles are required by law to be pedelec-type bicycles. Electric bicycles produced in Taiwan are mostly exported to Europe

III. PERFORMANCE RANGE OF AVAILABLE ELECTRIC BICYCLES

Table 2 gives a comparative overview of the performance ranges of today's commercially available electric bicycles according to the authors' market research.

TABLE 2 PERFORMANCE RANGE OF COMMERCIALLY AVAILABLE ELECTRIC BICYCLES

Speed	Average speed 19 km/h.	Max. Speed 32 km/h
Travel range(Full charge)	16–80 km	
Batteries Charging time	2–6 h	
Cycles of charge/discharge	Up to 400	

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
IARJSET
International Advanced Research Journal in Science, Engineering and Technology
AGNI-PANKH 16
Jawaharlal Darda Institute of Engineering and Technology, Yavatmal
Vol. 4, Special Issue 3, January 2017

Power consumption (Each full charge)	100–500 Wh
On-board power supply	12–36 V
Torque (Hill climbing ability)	up to 6% slope
Weight of Electric bicycle kit excluding original bicycle weight	4.6–22.8 kg
Price range	Rs 25000 - Rs 35000

It illustrates how widely the specifications of electric bicycles vary according to the bicycle design and the riding conditions for which the electric bicycle is designed.

IV. CLASSIFICATION OF ELECTRIC BICYCLES

Criteria for classification of electric bicycles have been determined such that they are independent of the country and the purpose of use. These are the bicycle kit type, motor type, motor assembly, assist type, throttle type, motor placement, and battery type (Table 3). Even though technical aspects do exist, both the assist and the throttle types depend largely on the rider's personal preference. The design of the assist type can be significantly influenced by the country's regulation. Unless close attention is paid, both full- and half-assist types can look the same at first glance.

TABLE 3 CRITERIA FOR CLASSIFICATION OF ELECTRIC BICYCLES

Sr. No	Parameters	According to
1	Bicycle Kit Type	Custom built Add on
2	Motor Type	Brushed dc machine Brushless dc machine
3	Motor Assembly232	Gear Hub Friction
4	Assist Type	Full-assist Half-assist
5	Throttle Type	Thumb throttle Twist throttle Push button
6	Motor Placement	Front wheel Rear wheel
7	Battery Type	Lead acid NiMH Others

V. PERFORMANCE EVALUATION

Criteria have been defined to evaluate the performance of electric bicycles. These are technical performance, practicability, design, environmental friendliness, and cost and economics. Even though the technical maturity of electric bicycles has been, and is still, improving, still more work needs to be done to make electric bicycles competitive with other vehicles. This includes more research on the durability and lifetime of such bicycles, the long charging time of batteries, and the sparse availability of charging stations.232

VI. THEORETICAL BACKGROUND

The total power Ptotal required to drive the bicycle is given by the sum of the power to overcome the air drag P_{drag} , the power to overcome the slope Phill , and the power to overcome the friction $P_{friction}$. Equations (1)–(4)show the relationships as discussed in [6] and [8], where the symbols for the parameters, their units, and some remarks are summarized in Table 15.

(1) $P_{total} = P_{drag} + P_{hill} + P_{friction.}$

(2) $P_{drag.} = \underline{C_d \cdot D \cdot A}.\ (Vg + Vw)^2.\ Vg.$

(3) $P_{hill} = 9.81 \cdot G \cdot Vg \cdot m.$

(4) $P_{friction} = 9.81 \cdot m \cdot Rc \cdot Vg.$

The three cases that can be distinguished according to Wilson's Bicycle Science [8] correspond to the following riding conditions:

■ Case 1

At speeds greater than 3 m/s (≈6 mi/h), the majority of the power is used to overcome the air drag → Flat ground, high speed:

→ Pdrag ↑↑, Phill, = 0, Pdrag > Pfriction .

■ Case 2

At speeds less than 3 m/s (≈6 mi/h) and at level surfaces, the majority of the power is used to overcomethe rolling resistance→ Flat ground, low speed:

→ $P_{friction}$ ↑↑, P_{hill}, = 0, $P_{friction} > P_{drag}$.

IARJSET
ISSN (Online) 2393-8021
ISSN (Print) 2394-1588
International Advanced Research Journal in Science, Engineering and Technology
AGNI-PANKH 16
Jawaharlal Darda Institute of Engineering and Technology, Yavatmal
Vol. 4, Special Issue 3, January 2017

■ Case 3
On steep hills, the power required for overcoming air drag and rolling resistance is small when compared with the power required to overcome the slope → Hilly ground, low speed:
→ P_{hill} ↑↑, P_{hill},> P_{drag}, $P_{hill} > P_{friction}$

VII. POWER REQUIREMENT EXPERIMENTAL INVESTIGATION

For these experiments, four different riders rode the test bicycle without using the dc motor under different riding conditions. The experiments were conducted for speeds up to 12 mi/h (19 km/h), which is typical for city rides. The air density is approximated to be constant. Furthermore, based on the theoretical results, rolling and drag coefficients are assumed to be almost constant and are not investigated in detail. Three series of measurements were carried out:
1) total power P_{total} versus ground speed Vg as a function of load m
2) total power P_{total} versus ground speed Vg as a function of slope grade G3) total power P_{total} versus ground speed Vg as a function of wind speed Vw .The series of measurements for total power Ptotal versus ground speed Vg as a function of load m is as shown .

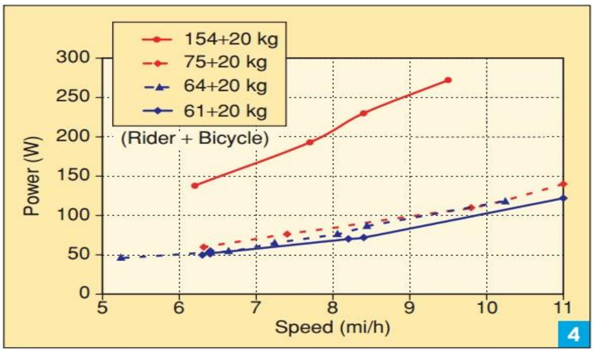

Fig.1. Influence of the weight of the rider and bicycle influence on the power versus speed curve no wind, constant slope G ≈ 1%.

For a given ground speed Vg, small variations in load result in small variations in power requirement (20 W difference of required power for 15-kg load variation). For doubled load, twice the power is required, as is illustrated by comparing the curves for (64+ 20)kg and (154+ 20) kg load. Generally, a heavier rider also has a larger effective area which increases the power need to overcome the air drag (2) and accounts for the nonlinear increase from the curves obtained for (64+ 20) kg and (154+ 20) kg load. An addition of 10 kg to the bicycle systems requires additional power of approximately 10–15 W. Thus, there is not a significantly larger amount of energy needed to propel the bike if the load difference is less than a few kilograms. The series of measurements, total power Ptotal versus ground speed Vg as a function of the slope grade G , visualizes the correlation of (3). Figure shows the most complete set of measurements illustrating this analysis.) For a given ground speed Vg, Pfriction is constant, but Phill is directly proportional to the slope grade G. Thus, neglecting the Pdrag , Ptotal increases linearly with the slope grade G. For approximately an 80-kg weight of rider and bicycle, 320 W (47 Nm torque) are required to climb up a reasonable slope of 4% at 10 mi/h.

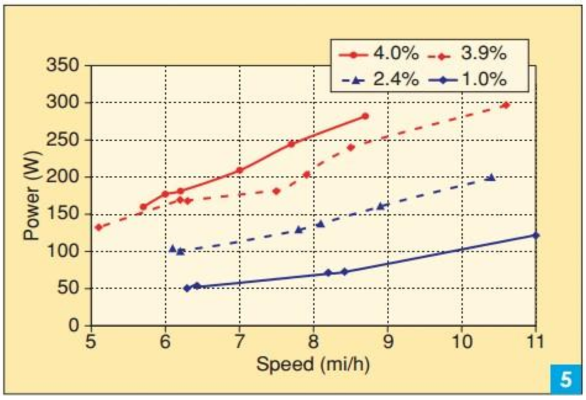

Fig.2 Influence of the slope of the power versus speed curve

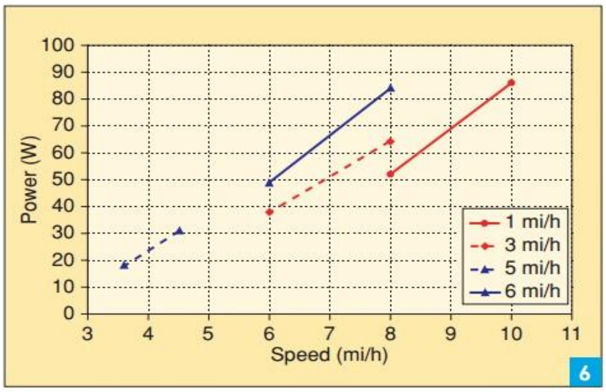

Fig. 3 Influence of the head wind on the path on the power versus speed curve

With electric bicycles rated at the maximum power allowed by federal law of 750 W, the maximum torque capability at 10 mi/h is 110 Nm. As a result, the steepest slope electric bicycles can climb at 10 mi/h ground speed is 8%. It is important to note that unless riding on hilly terrain, city rides usually need high torques only for a short period of time. Therefore, motors designed for city rides can have rated power below the federal law provisions.The measurement results for total power Ptotal versus ground speed Vg as a function of head wind Vw (Figure 6) are in line with (2).

(Note that similar results have also been obtained with riders other than the one of Figure 6, but the results of Figure 6 have been selected as they are the most complete set of measurements illustrating this analysis.) With increasing Vw, the power requirement increases. However, due to the very stochastic nature of wind, this experiment only provides a rough idea of the trend.

VIII. CONCLUSIONS

The issues associated with electric bicycles may be addressed by custom-designed drives that are most efficient over a given operating cycle. These include city bicycles, hill bicycles, distance bicycles, and speedy bicycles. The results of the studies listed here can serve as a platform to improve electric bicycle performance if new drive systems are designed around key parameters that will result in improvement of the system performance. Furthermore, they can be used for comparison of existing drives in a systematical, comprehensive, and technical way.

REFERENCES

[1] F.E. Jamerson, "Electric bikes worldwide 2002: With electric scooters & neighborhood EVs," Electric Battery Bicycle Co, Naples, FL, 2002.

[2] B. Kumar and H. Oman, "Power control for battery-electric bicycles," in Proc. NAECON '93—National Aerospace and Electronics Conf., vol. 1, May 24–28, 1993, pp. 428–434.

[3] E.A. Lomonova, A.J.A. Vandenput, J. Rubacek, B. d'Herripon, and G. Roovers, "Development of an improved electrically assisted bicycle," in Proc. 2002 IEEE Industry Applications Soc. Ann. Meeting, October 13–18,2002, pp. 384–389.

[4] Muetze, A.G. Jack, and B.C. Mecrow, "Brushless-dc motor using soft magnetic composites as a direct drive in an electric bicycle," in Proc. 9th European Conf. Power Electronics and Applications (EPE), Graz, 2001, Paper 350.

[5] Muetze, A.G. Jack, and B.C. Mecrow, "Alternate designs of brushless-dc motors using soft magnetic composites," in Proc. 15th Int. Conf. Electrical Machines (ICEM), Bruges, Paper 237, 2002.

[6] W.C. Morchin, "Battery-powered electric bicycles," in Proc. Northcon'94, Oct. 11–13, 1994, pp. 269–274.234