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Design of Electric Bike with Higher Efficiency

Rahul Sindhwani [a,*], Punj L. Singh [b], Anjum Badar [a], Ankur Rathi [a]
[a] Department of Mechanical & Automation Engineering, ASET, Amity University, Noida, U. P., India
[b] Department of Computer Science Engineering, ASET, Amity University, Noida, Uttar Pradesh, India

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Abstract

This paper is based on the future needs of one normal being. A shift away from conventionally-fuelled land transportation vehicles towards greater use of renewable energy fuel sources is needed to manage increasing vehicle usage and associated adverse environmental and human health impacts. Power assisted electric bicycles (PAEBs) provide a means to reduce vehicle emissions within urban areas was first stated by Graham S. Aikenhead [1]. The paper is to represent the improvement of 50% in efficiency of e-bike with hub motor incorporated in the rear wheel for producing the initial torque required to set the vehicle from rest to motion and main motor incorporated along with the chain drive for further power transmission which will eventually lead improvement that would be visible in the final model.

1. Introduction

This paper presents the ongoing research and development of “The Improved E bike” - the newer version of the ordinary e-bike with enhanced performance and improved characteristics. Electric bikes have simultaneously gained popularity in many regions of the world and some have suggested that shared electric bikes could provide an even higher level of service compared to existing systems. This paper represents a two passenger e-bike unlike the present versions available in the market that supports only the rider without the pillion rider. This paper outlines system requirements to successfully develop and deploy an electric bike, focusing on system architecture, structure, aerodynamic characteristics, operational concepts, and battery management. Although there is little empirical evidence, improved electric bike could be feasible, depending on demand and battery management, and can potentially improve the utility of existing e bikes.

The various parameters that would be covered in our improved version of e-bike can be broadly classified in the following categories:

1.1 Speed

Speed in its basic term is defined as distance covered per unit time, i.e. each of the possible gear ratios of a bicycle or bike. As according to the various sources and references, the speed of the presently existing electric bikes is somewhere around 40-45 km/hr, at maximum. Most of the motor driven bike has a speed less than 50 kilometres per hour. The enhanced e-bike can provide an improved speed as high as that of 85-90 km/hr and improved efficiency is the greatest assets to this newer version of e-bike.

Corresponding Author,
E-mail address: rsindhwani@amity.edu

1.2 Aerodynamic Structure

Aero forces go up with the square of the speed, meaning that if you double the vehicle speed, you increase the total drag resistance by four times. What's worse from a rider’s point of view is that horsepower requirements to reach a given speed go up with the cube of velocity. At 50 mph it takes 8 times as much power to push the bike through the air as it does at 25 mph. Therefore, if top speed is the goal, anything that reduces frontal area and makes the vehicle's shape more streamlined is crucial.

2. Research Gap

Electric bikes come in many styles and performance characteristics, but the primary technology is the same. The vast majority rely on lead acid batteries to provide energy to a hub motor, usually on the rear wheel. Most electric bikes fall into two categories: scooter style electric bikes (SSEBs) or bicycle style electric bikes (BSEBs) was experimentally studied by Chris Cherry, et al [2] .The speed of an e-bike has long been of interest in day-to-day easy accommodation for covering large distances. Till now, many studies were conducted related to this particular area of Mechatronics. Many Researchers are till now working on design, development and improvements in this field. A broadly approved solution to a faster e-bike lies in improving its speed and its aerodynamic structure.

Mechatronics is a term originated in Japan in 1980s and is used to denote the combination of technologies. A formal definition of Mechatronics is ``the synergistic integration of Mechanics and Mechanical Engineering, Electronics, Computer technology, and IT to produce or enhance products and systems.'' Examples of such systems are Computers, Disk drives, Photocopiers, Fax machines, VCR, Washing machines, CNC machine tools, Robots, etc. Today's modern cars are also mechatronics product with the usage of electronic engine management system, collision detection, global positioning system, and others was first studied by Dr. S.K. Saha [3].

Aerodynamic structure is one of the major factors that present the finest potentials for improving the speed of the bike.What already has been done in the field of electric bikes can be understood by going through the facts been mentioned here. One major field of improvement that has not been covered yet is enhancement of the speed of the e-bike. All the various versions of the existing e bike provide a maximum speed of about 45-50km/hr. None of the existing e-bikes can overcome this speed. The proposed model is an attempt in mechatronics field to overcome this big challenge and thus it could be a leap step in the history of electric bikes.

The distinguished work already been done in the field of electric bike can be summarized as follows:

Table: 1. Contribution towards E-bike

S. No.	Author	Contribution
1	P. D. Kamble, S. P.Untawale, S. B. Sahare	P. D. Kamble, et al [4] investigated that Automatic Gear shifting mechanism and electric drive will provide general public with an economical version of electric two wheelers along with reduced human efforts and increase in speed by changing gears at regular velocity interval.
2	Christine Outram , Carlo Ratti, AssafBiderman.	The Copenhagen Wheel– the wheel that turns ordinary e-bikes, quickly and easily into electric hybrids with regeneration and real-time environmental sensing capabilities was given by Christine Outram, et al [5].
3	Justin Lemire-Elmore	The Power-Assisted Bicycle is an emerging form of transportation that attempts to merge the health and environmental benefits of a bicycle with the convenience of a motorized vehicle. According to recent amendments to the Motor Vehicle Safety Act, a power assisted bicycle may have up to 500 watts of electrical output and still be legally equivalent to a human-powered bike on the road was studied by Justin Lemire-Elmore [6].
4	Christopher Cherry, Stacy Worley, David Jordan	Christopher Cherry, et al [7] experimentally studied that the electric bicycle (e-bicycle) market varies greatly by product type and regional demand. Many Asia Pacific countries and some European countries have embraced the e-bicycle and are being excessively used.

3. Methodology

The two main parameters that will be discussed in this paper in order to enhance the efficiency of the e-bike are speed and the aerodynamic structure. These parameters are further discussed in detail below:

3.1 Speed

As far as speed of the e-bike is considered, the existing e-bike offers a speed of about 45 km/hr. In order to improve the speed of the e-bike, a chain drive is being attached to the currently working model of e-bike. Chain drives are among the oldest of the basic machine elements. There are three main types of motors in the marketnamely geared hub motors, crank drive motors and direct drive motors (considering the geared hub motor to be light weight, and small sized but with least performance as compared to crank drive motor and the direct drive geared motor) for making an e-bike much more efficient there is need of choosing the best combination of the above three motor can be utilised in many different ways i.e. initial torque, power booster depending upon the user benefits. Direct drive hub motors can go fast but they don't have significant hill climbing ability. They turn once for every revolution of the wheel so must be big and are about twice the weight of geared types. These geared type hub motors have internal planetary gears that keep the electric motor spinning an optimum speed and reduce the rpm for the wheel was studied by Jace Hobbs [8]. Zhenying Shao , et al [9] found out that everyone want faster speed so that e-bikers can cut down their commute time and allow them to ride more frequently than if they ride traditional bikes, especially during hot and windy days.

Chain drives offer non-slip, light-weight, inexpensive, compact power transmission compared to belts or gears was experimentally studied by James C. Conwell, et al [10]. Chain drives consist of two sprockets, the larger sprocket and the smaller sprocket. This is shown below:

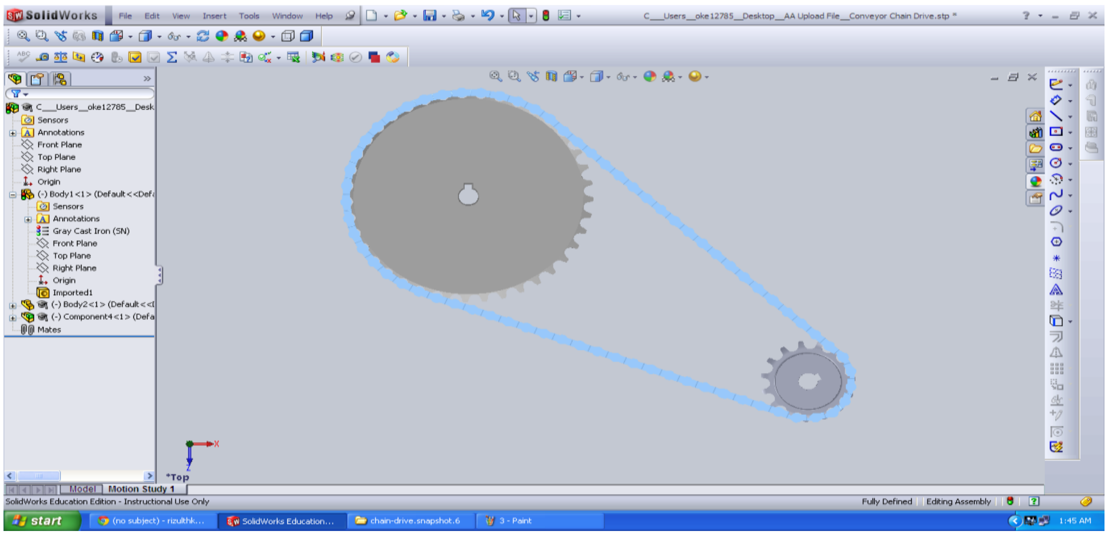

Fig: 1. Simulation of the motor shaft is done after applying of 21 N-m torque

The larger sprocket is being attached to the main motor which is placed at the centre in our model and another smaller sprocket is connected to the rear wheel.

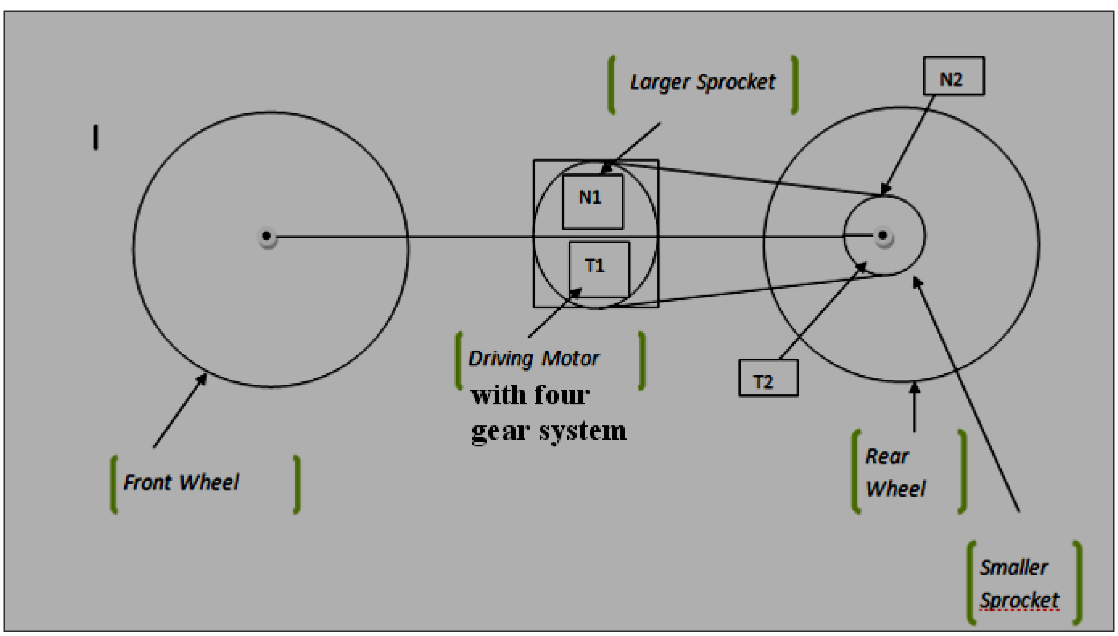

Fig: 2. Theoretical concept diagram

Mathematically, the teeth ratio is given as N1/N2 = T2/T1
Where,
N1= Speed in larger sprocket.
N2= Speed in smaller sprocket.
T1= number of teeth in larger sprocket.
T2= number of teeth in smaller sprocket.
Generally, T1/T2 is in ration 2:1.
Assuming N1 to be 500,
Then,
N2= (N1*T2)/T1= 1000
Thus, we can see that speed is nearly doubled.
So we can say that our bike is 60% much more efficient than the old version of e-bike.

3.2 Aerodynamics

The aerodynamic of the bike mainly depends on speed. Speed in turn is directly proportional to twice of the drag force and to the cube of horse power (hp) required.

The total power Ptotal required to drive the e-bike is given by the sum of the power to overcome the air drag “Pd” , the power to overcome the slope “Ph”, and the power to overcome the friction “Pf”, i.e.,

Ptotal= Pd+ Ph+ Pf

Where,

Pd = Cd * D * A* (v g + vw)2* v g

Ph = 9.81 * G * v g * m

Pf = 9.81 * m * Rc * v g

Aerodynamic drag for a given velocity can be reduced by reducing the value of two variables: Cd (coefficient of drag) and Frontal (cross sectional) Surface Area. Aerodynamic drag increases exponentially with velocity. Therefore, reducing Cd and Frontal Surface Area offers enormous energy savings for even slight increases in velocity.

Also, to enhance the aerodynamic structure of the e-bike, there will be a 6 " - 12 " space between the inside of the windshield and the front handlebars. Batteries, carry bags, body upper torso etc. all add extra resistance to the front winds, thereby, decreasing motor and battery efficiency and making it more difficult to run the bike. Since these factors can’t be completely eliminated, therefore it becomes a necessity to mount them in an aerodynamic way.

In order to reduce the resistance offered by the wind, the bike is fabricated with a V shaped front windshield from clear lightweight plexiglass which will provide a fantastic pointed shape to cut through the front wind resistance. The windshield will be relatively lightweight, less than 2.5 kg and it will mount to the front forks and steering stem so it is always pointed in the direction of the turns/travel.

Aerodynamics in Total (combination of rider aerodynamics and bike aerodynamics) – 65%

Bicycle Aerodynamics ≈15% of total power use. (≈25% of total aerodynamics)

Wheels – 7-11% of total aerodynamics

Fork – 6-9% of total aerodynamics

Frame – 4%-9% of total aerodynamics

Other – 2-4% of total aerodynamics

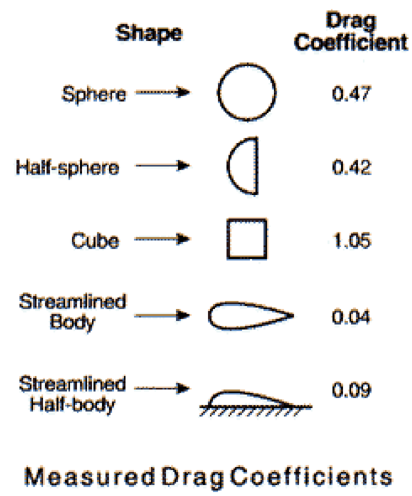

Fig: 3 Measured drag coefficient

Further, in order to increase the distance, speed and battery/ motor efficiencies, an aerodynamic setup on the bike may be the best way to increase efficiency by 15% of total power use. (≈25% of total aerodynamics)

4. Improvement In Efficiency

Earlier versions of e-bike had the following specifications:

- Maximum Speed- 40km/hr
- Maximum Range- 70-75 Km

In order to improve the speed of e-bike to about 100 km/hr, following factors has been taken into account:

Improvement = (aerodynamic structure) + (technology used)

From above research it is understood that 15% of the maximum speed is attained because of its best aerodynamic structure.

Aerodynamic speed (0.15*100=15kmph)

Increase in efficiency can be calculated as follows:

Efficiency = [{(New speed) - (old speed)}/ (New speed)]*100

= [{(100-40)}*100]/100

= 60%

5. Conclusion

It can be concluded from this paper that the overall efficiency of the bike will definitely be improved by working on the parameters discussed earlier. Also, a completely new dimension of the bike will be designed with enhanced features. If the venture proves to be successful then an enhanced e-bike can be available at a much cheaper price. The design of the e- bike can also be improved further in terms of its appearance in view of the 21st century people. The bike can prove to be an ideal for promoting the concept of "GO GREEN AND CLEAN".

6. Future Scope

The bike can further be improved by using solar panels on the front and the rear frames of the mudguards or other places which would be responsible for trapping solar energy & converting the same into electric energy thereby improving the battery's efficiency.

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