Experimental Study of Pedelec E-Bike Using Modified Mid Drive Motor

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Abstract. In small island areas, people still use fossil fuel vehicles as their mode of transportation. This will cause environmental damage. One solution to this problem is developing the electric bike. This study uses a power-assisted bicycle type electric bicycle, consisting of a battery, a dc motor, a motor controller, and a throttle motor. From the test results, the motor can be used to support the rider. The problem is that the rated power is still more oversized than the engine can receive, where the temperature rises sharply from 30. 6 ° to 56.8°C in 21 minutes. The consequence was motor burnout because the motor forced to turn the front wheel over time. For right now, this e-bike suitable tourism bike in a short area so we can make sure the motor temperature did not exceed 50°C.

1 Introduction

Many transportation modes, such as cars, motorbikes, and public transportation, have begun to leave liquid-based energy sources (gasoline, diesel) and switch to using electrical energy sources. Almost all big cities promote electric energy-based vehicles and provide facilities for charging electrical energy sources for free . It is very different from the situation in small island areas, where people still use fossil fuel (petroleum) vehicles especially motorcycle as their mode of transportation and have large dependency [1], [2].The emission from these vehicle will cause environmental damage and contribute to climate change. This needs to be reduced because considering the source of fuel is obtained from the mainland and the cost of delivering this fuel is quite large.

One of the way is developing electric bike. E-bike have low electricity consumption, easy to maintain, relatively cheap, and useful for human health [3], [4]. For example, Chinese people use electric bicycles as much as 25% - 60% as a substitute for cars [5]. This shows that E-bike have a role in solving problems of air pollution and dependence on fuel [6].

E-bike can be classified into two categories: pure electric bike and power-assisted bicycle, or called pedelec [7]. E-bike mainly constructed using battery, motor DC, motor controller, and motor throttle [8]. The present paper deals with the development and experiment of E-bike prototype designed at the Department of Electrical Engineering of the Maritime University of Raja Ali Haji.

2 Method

2.1 The E-Bike Prototypec

This vehicle developed not to fully electric operated but to support the rider with electric motor while rider pedaling as shown in **Figure 1.** This e-bike constructed using 24 VDC 10Ah Lithium Ion Battery, throttle, motor controller, free wheel, 24 VDC 350 Watt brushed motor and configuration (**Figure 2**). DC motor installed in middle frame. Free wheel connected by welding in front crank chainwheel from regular bike (**Figure 3**) so the movement of the front pedal can be assisted by an electric motor. Lithium batteries have been implemented in previous studies [9], [10] and have become the primary power source for electric bicycles.

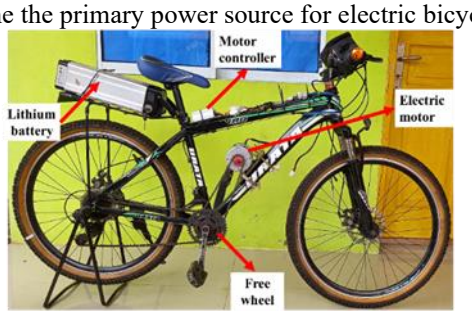

Fig. 1. E-bike pedelec prototype.

Fig. 2. E-bike component configuration in this prototype.

Fig. 3. Free wheel welding to front chainwheel

2.2 Performance Evaluation

Laboratory tests and experimental tests have been carried out to analyze the e-bike performances. The laboratory test was carried out by connecting a 24V 350W electric motor with pedals and rear gear from fourth gear until six gear. This test done to obtain results in the term of speed (RPM), voltage, current, power and torque contained in DC motors by comparing with percentage handle throttle and rear gear.

Voltage and current are obtained using a multi meter in series and parallel. **Figure 4** illustrates the voltage and current data collection. Angular speed is obtained by testing the rotation of the rear wheel of a bicycle using a tachometer (**Figure 5**) [11]. The rear wheel is fitted with a tachometer sensor sticker. Power obtain from voltage and current data and calculated using equation (1). Torque is defined as rotational force obtains from power divided by angular speed using equation (2). The experimental test was conducted to determine the e-bike performance and the temperature change while riding the e-bike.

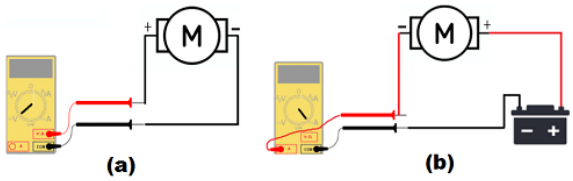

Fig. 4. Illustration voltage (a) and current (b) measurement using a multimeter.

Fig. 5. RPM measurement using tachometer.

$$P = \frac{V}{I}$$

where:
P = Power (Watt)
V = Voltage (V)
I = Current (A)

$$T = \frac{P}{2\pi\omega}$$

where:
T = Torque (Nm)
P = Power (Watt)

3 Result And Discussion

3.1 Laboratory Test

A laboratory test for this prototype was conducted to measure tire angular speed using a tachometer and compared with voltage and current measurement using a multimeter. The experimental results are shown in **Figure 6**, and **Figure 7** indicate that voltage and current have a positive relationship with the angular speed. Angular speed increase as higher gear. The voltage produced by 25% handle throttle has an average difference of 7.5 V and 12.3 A to another percentage throttle. The difference voltage between 50%, 75%, and 100% throttle is only 1.5 V. This consequence to angular speed have a different dramatic value. Laboratory tests and experimental tests have been carried out to analyze the e-bike performances.

The motor can produce power 40 - 450 Watt and torque 1.6 - 4.5 Nm in this laboratory test (**Figure 8**). Thus, the electric motor can produce more power than stated in the specification, 350 W. The increase in power and torque generated corresponds to motor capability moving the chain and tire [12].

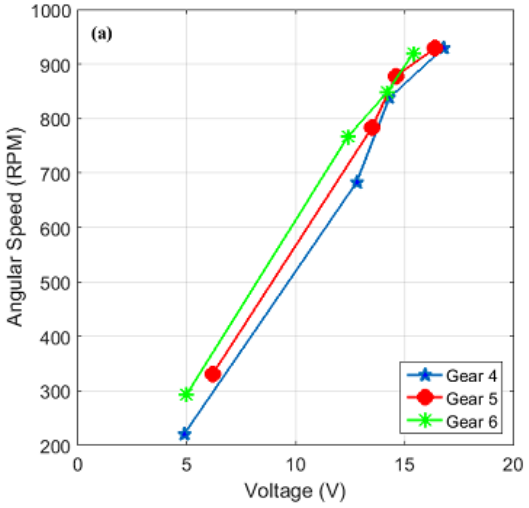

Fig. 6. Results of voltage measurement compared to angular speed in different gear and percentage handle throttle**.**

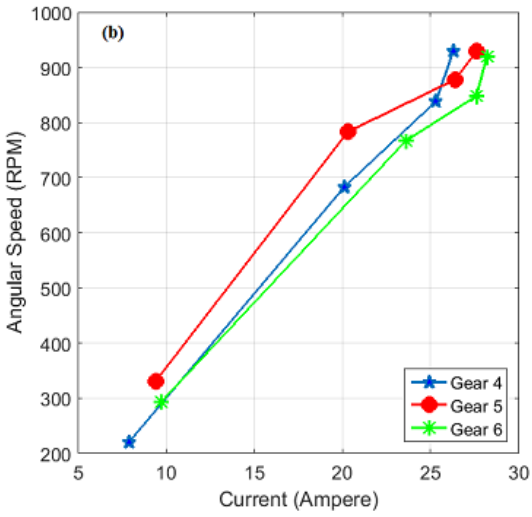

Fig. 7. Results of electrical current measurement compared to angular speed in different gear and percentage handle throttle**.**

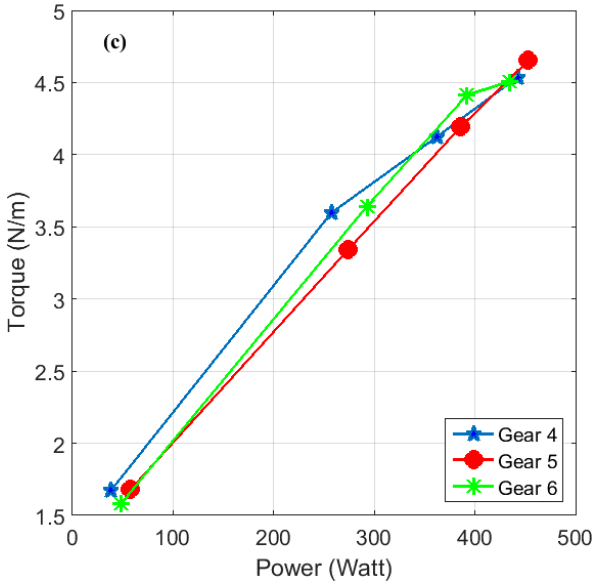

Fig. 8. Results of power compared to torque in different gear and percentage handle throttle**.**

3.2 Experimental Test

Experimental tests have been performed to analyze the e-bike performance and conducted by riding ebike through circle area in the local business park. While riding, we record the motor temperature as shown in **Figure 9**. Based on the test, we can feel the motor help reduce pedal power from feet and assist the bike in moving forward, so we feel lighter when pedaling the bike (**Figure 10**). **Figure 11** shows this e-bike can be operated by the user without a manual pedal. In this test, the motor temperature rises from 30.6ºC to 56.8ºC in 21 minutes, as shown in **Figure 12**. The result of this action was motor burnout, as shown in **Figure 13**. Electric motor burns because the motor forced to turn the crank set in the front wheel over time. We already use fuse 20A to make it safe, but the power that went to the motor is still more extensive than the motor can receive. The motor's unable to produce the required torque is caused by the significant resistance in the transmission mechanism between the gear and chain [13].

Fig. 9. Field test location and motor temperature record coordinate.

Fig. 10. Motor help rider to pull front wheel to make ebike move.

Fig. 11. E-bike move without pedaling.

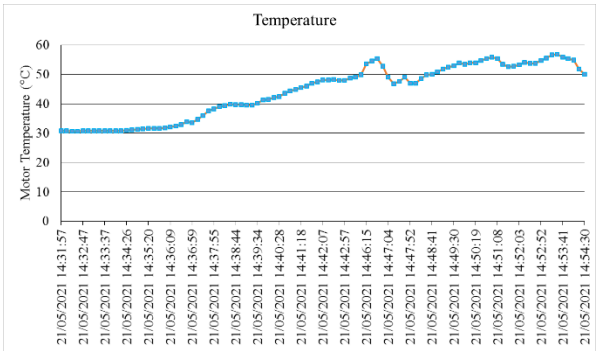

Fig. 12. Motor temperature record based time riding.

Fig. 13. Motor burn out as a result of experimental test.

4 Conclusion

This paper has described the development of e-bike using brushed motor DC, lithium battery, and freewheel. The preliminary tests have been carried out to see the relation between angular speed, voltage, current, power, and torque. From this study, we already demonstrate the capability of this e-bike prototype. Field test give result that motor can be used to support or assist rider. The problem is the rated power still bigger than motor can receive so the motor burn out. Therefore, there needs to be changes, especially in the use of electric motors if we want to make this ebike can perform in street. For right now, this e-bike suitable tourism bike in short area so we can make sure the motor temperature not exceed 50ºC.

Acknowledgement

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