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A simulation and experimental study of operating characteristics of an electric bicycle

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Abstract

Electric bicycle is attracting more people's attention around the world because it is one of environmentally-friendly vehicles as well as a zero-emissions vehicle. In order to develop a high performance electric bicycle, a simulation study of its operating characteristics is conducted based on effects of key parameters such as rider's mass, wind speed and slope. Operation of this bicycle is simulated based on dynamic equations with certain operating conditions. Matlab-simulink is used to solve these dynamic equations. Based on required power obtained from this simulation, a suitable power is selected for motor of the electric bicycle. In order to support the simulation study, an experimental study is conducted to examine operating characteristics of the electric bicycle in two cases: human power only and human power with assistance of an electric motor. Experimental data is acquired using LabVIEW programming. The experimental results are compared with simulation results to validate the presented simulations.

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Key words : Electric bicycle, Bicycle dynamics, Electric motor, Matlab-simulink, LabVIEW

1. Introduction

Recently, the world is facing with big challenges including depletion of fossil fuels and global warming caused by exhaust emissions from conventional vehicles fueled with gasoline or diesel. In this situation, electric vehicles (EVs) have a great potential to overcome these challenges [1]. EVs do not have combustion and do not use fossil fuel [2]. Therefore, they are very friendly for environment because of their zero emission. Among of EVs, electric bicycle is being motivation for researchers to investigate and develop because it is cheaper than the other EVs [3]. Electric bicycle is also good for maintaining and repairing. Besides, it is not only suitable for driving in city, but also particularly useful for people living

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in hilly or windy areas (e.g. South Korea) where riding a bicycle would spend more energy to overcome wind resistance or go uphill. Therefore, the investigation and development of electric bicycle are necessary to use it in the real applications.

In order to develop a high performance electric bicycle, a simulation study is conducted to examine its operating characteristics based on effects of input parameters such as rider's mass, wind speed and slope. Operation of this bicycle is simulated based on dynamic equations with certain operating conditions. Matlab-simulink is used to solve these dynamic equations. Based on optimized mechanical power obtained from this simulation, a suitable power can be selected for motor of the electric bicycle. In order to support for the simulation study, an experimental study is also conducted to examine operating characteristics of the electric bicycle in two cases: human power only and human power with assistance of an electric motor. Experimental data is acquired using LabVIEW programming.

2. Simulation study

2.1 Bicycle dynamics

In order to analysis dynamic characteristics of the electric bicycle, a free body diagram of the bicycle is established, as shown in Fig. 1.

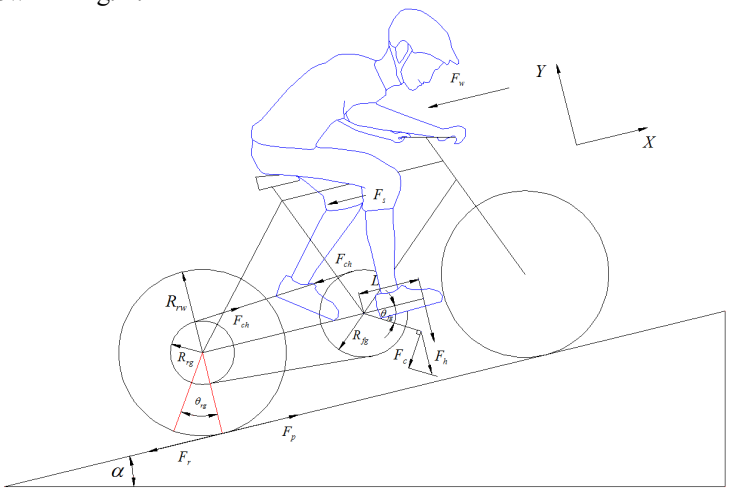

Fig. 1 Free body diagram of the bicycle

The motion of bicycle obeys Newton's second law, which is described by:

$$F_p - (F_r + F_s + F_w) = M\frac{d^2x}{dt^2} \quad (1)$$

Where, F_p is propulsion force, F_r is rolling resistance force, F_s is slope resistance force, F_w is wind resistance force, M is total mass of bicycle (M_b) and rider (M_r), and x is distance (m)

In order to support rider during pedalling, this study uses a DC motor which is installed in the rear wheel. The dynamics of the DC motor is described by Equations (2) and (3) [4]:

$$L_a.\frac{di_a}{dt} + i_a(t).R_a + K_b\omega_m = U_a. \quad (2)$$

$$J.\frac{d\omega_m}{dt} + B_1.\omega_m + T_L = K_b.i_a(t) \quad (3)$$

Where, i_a is the armature current, R_a is the armature resistance, U_a is the terminal voltage of DC motor, L_a