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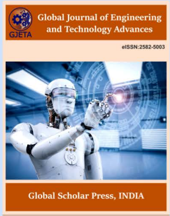

(Research Article)

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Research on SimMechanics application to investigate the engine of a self-balancing two-wheeled vehicle model

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Abstract

Since its inception in 2001, self-balancing two-wheeled vehicles have been a topic that has been widely researched around the world. There are many different methods to maintain the balance of a two-wheeled vehicle. This article presents a study on the application of SimMechanics to investigate the engine of a self-balancing two-wheeled vehicle model. Survey results show that when the engine rotates steadily, it will not be able to create torque to help the vehicle balance. At the same time, the voltage (when the torque is largest) and speed (when the engine rotates stably) of the engine have a linear relationship.

Keywords: Self-balancing two-wheeled vehicles; SimMechanics; Torque; Speed

1. Introduction

Today, along with the rapid development of science and technology, many ideas for compact fast-moving devices to replace walking have begun to appear in travel needs. Understanding those needs, since 2001, balanced two-wheeled vehicles - considered a revolutionary vehicle in personal transportation - began to be widely introduced around the world. Since its inception in 2001, self-balancing two-wheeled vehicles have been a topic that has been widely researched around the world. There are two-wheeled vehicle balancing control methods as follows:

Steering angle control method: this method has research articles by Y. Tanaka and T. Murakami [1], research by J. Yi, D. Song, A. Levandowski, and S. Jayasuriya [2], research by P. Pongpaew [3],...

Gyroscope method: this method has been researched and applied by Lit Motors Inc., research by A. V. Beznos, A. M. Formalsky, E. V. Gurfinkel, D.N. Jicharev, A. V. Lensky, K. V. Savitsky, and L. S. Tchesalin [4], research by T. Bui and M. Parnichkun [5],...

Balancing method using flywheel: Murata Boy product was developed by Murata Manufacturing Co., Ltd in 2005 [6], ABRB (Auto - Balanced Robotic Bicycle) model of 4 members Aamer Almujahed, Jason Deweese, Linh Duong and Joel Potter of George Mason University, USA [7].

With the advantage of being compact and flexible, two-wheeled balanced vehicles have been widely used in daily life. However, it still has limitations: low travel speed, short distance, which can cause falls for the user. In general, balanced two-wheeled vehicles are suitable for moving in small areas such as parks, factories, etc. The limitations of balanced two-wheeled vehicles were quickly resolved with the advent of balanced electric motorbikes. A balanced electric motorbike is a type of transport vehicle that has a structure like a motorbike - two wheels with parallel axles, uses clean

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energy source of electricity, and is especially capable of self-balancing. When used, balanced electric motorbikes bring high safety to traffic participants, reduce environmental pollution, and can travel long distances and at great speed. Many car corporations in the world have continuously developed and launched many self-balancing electric motorbike models such as Honda, Lit Motors,... This is a vehicle that carries the trend of the future. This study focuses on analyzing a balanced electric motorbike model to investigate the impact of the engine in a two-wheeled vehicle model using a reaction flywheel.

2. Material and methods

Modeling a system is essential to building a theoretical basis, helping to understand the physical nature of the system as well as the premise for design and control. This section examines the influence of the engine in a self-aligning two-wheeled vehicle model.

The balanced electric motorbike model depicted in Figure 2.1 includes: flywheel (1) attached to the engine (2), wheels (3) and chassis (4).

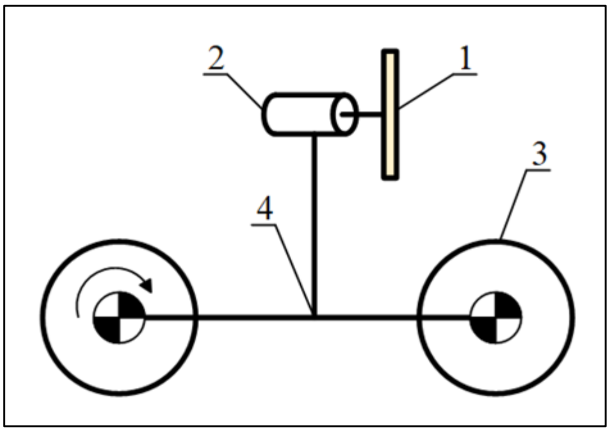

Figure 1 Survey model of balanced electric motorbike

The parameters of the balanced electric motorbike system are presented in table 1:

Table 1 Table of parameters of the balanced electric motorbike system

Symbol	Unit	Describe
θ	rad	Angle of inclination of the vehicl
φ	rad	Rotation angle of flywheel
J_1	kg.m2	Vehicle moment of inertia (including engine stator)
J_2	kg.m2	Flywheel moment of inertia (including engine rotor)
c_1	N.m.s/rad	Rotational friction coefficient between the wheel and the road surface
c_2	N.m.s/rad	Flywheel shaft friction coefficient
m_r	kg	Mass of motor rotor
m_s	kg	Mass of motor stator
m_l	kg	Vehicle mass
m_{bd}	kg	Mass of flywheel
m_1	kg	Mass of vehicle and engine stator
m_2	kg	Mass of flywheel and engine rotor
l	m	Distance from wheel base to vehicle center of gravity (including flywheel)

l_1	m	Distance from wheel base to vehicle center of gravity (without flywheel)
l_2	m	Distance from wheel base to flywheel rotation axis
K_t	Nm/A	Motor torque constant
K_b	V.s/rad	Electromotive force constant of the motor
R_a	Ω	Motor inductor resistance
g	m/s2	Gravitational acceleration

3. Results and discussion

3.1. Modeling DC motors

The purpose of modeling a DC motor is to find the relationship between the motor's torque and the voltage applied to the motor.

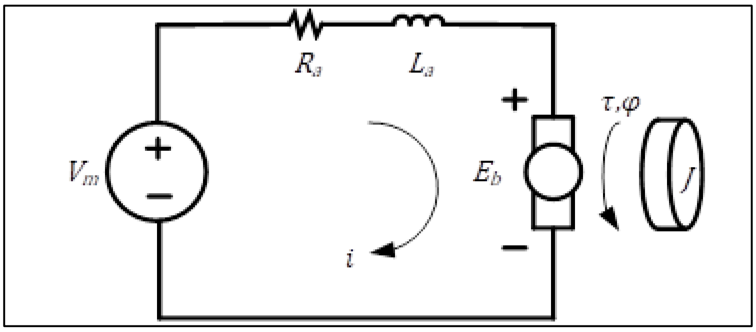

Figure 2 Equivalent circuit diagram of a DC motor

According to Kirchhoff's 2nd law:

$$V_m - iR_a - L_a\frac{dt}{di} - E_b = 0 \qquad (2.1)$$

Where i: current through the armature of the motor; L_a: inductance of the motor's armature winding; R_a: net resistance of the motor winding; E_b: electromotive force of the motor

The motor's reactive power E_b is proportional to the rate of change of magnetic flux and therefore also proportional to the motor's angular velocity. The motor's reactive power is calculated as follows:

$$E_b = K_e\frac{d\varphi}{dt} = K_b\dot{\varphi} \qquad (2.2)$$

Assume the effect of armature winding inductance is negligible (because L_a<<R_a). Substitute formula (2.2) into (2.1):

$$i = \frac{V_m - K_b\dot{\varphi}}{R_a} \qquad (2.3)$$

Therefore, the torque generated from the motor is calculated as follows:

$$\tau = K_t i = K_t\frac{V_m - K_b\dot{\varphi}}{R_a} \qquad (2.4)$$

Comment: From equation (2.4), when V_m=K_b φ˙ then τ=0. Then the engine will rotate evenly in the absence of friction. Next, the SimMechanics tool is applied to investigate the relationship between the input voltage and the motor's generated torque.

3.2. SimMechanics application for engine surveys

SimMechanics is a tool of Matlab software that helps simulate a mechatronic system. It links the mechanical and control sections together. 3D models are designed from software such as: SolidWorks®, Autodesk Inventor®, PTC® Creo™

(Pro/ENGINEER®),... Then, CAD file data is exported to Matlab/SimMechanics data in the form of ". xml". There are two methods to export to ".xml" file: SimMechanics First Generation and SimMechanics Second Generation. In this part the SimMechanics First Generation method is used to export data from a 3D environment to Matlab.

The engine survey model was built on SolidWorks software and consists of two components: the engine (DC motor) (1) and the rotating disc (2) linked together by a rotating joint, shown in Figure 3. The 3D file after being exported from SolidWorks to Matlab is in ".xml" format. The command "mech_import('.xml')" is used to transfer the file with the extension ".xml" to the SimMechanics environment and the results are shown in Figure 4.

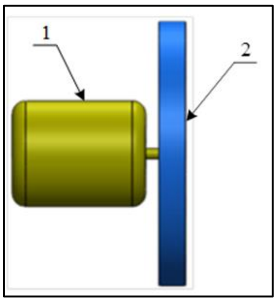

Figure 3 3D model of DC motor and rotating disc in SolidWorks

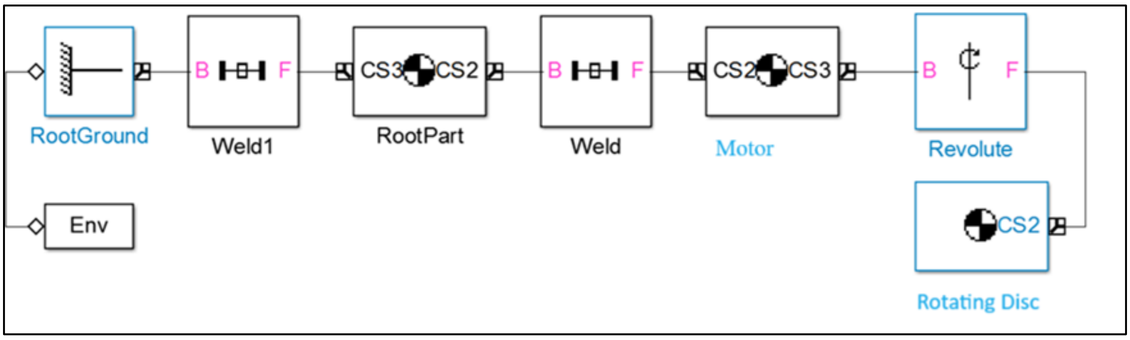

Figure 4 Engine model after exporting via SimMechanics

In Figure 4, the "Motor" block is connected to the "Rotating Disc" block through the "Revolute" joint. The remaining blocks were created by SimMechanics as a simulation environment.

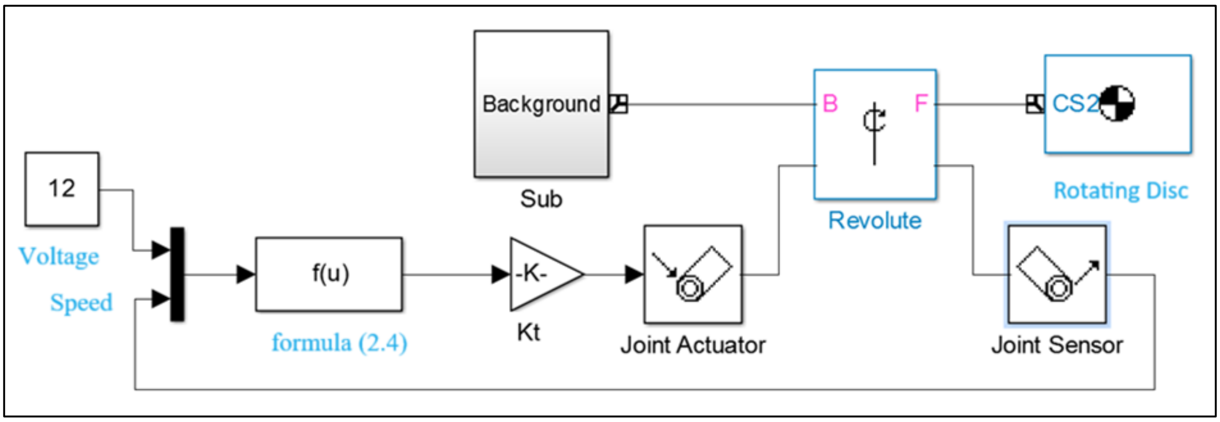

Figure 5 Survey model of DC motor

The DC motor survey model is shown in Figure 5. The input voltage V_m is supplied respectively: 9V, 12V, 15V. The engine moment is generated after going through the calculation steps in the block " Formula (2.4)" and " K_t". From there, the moment acting on the "Revolute" rotating joint and the velocity are read through the "Joint Sensor" block. According to formula (2.4), the motor's torque value will decrease to zero and the speed will gradually increase to a certain value. The results of motor torque and speed are shown in Figure 6 and Figure 7.

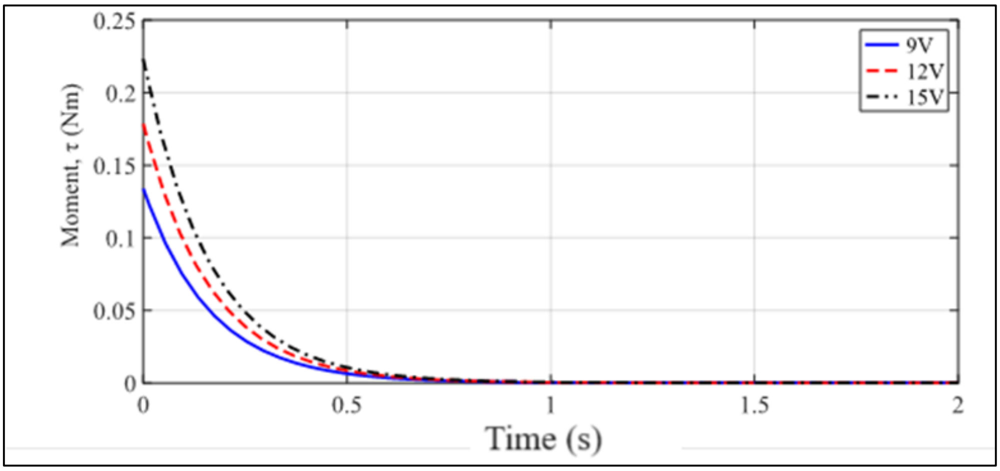

Figure 6 Graph of motor generated torque

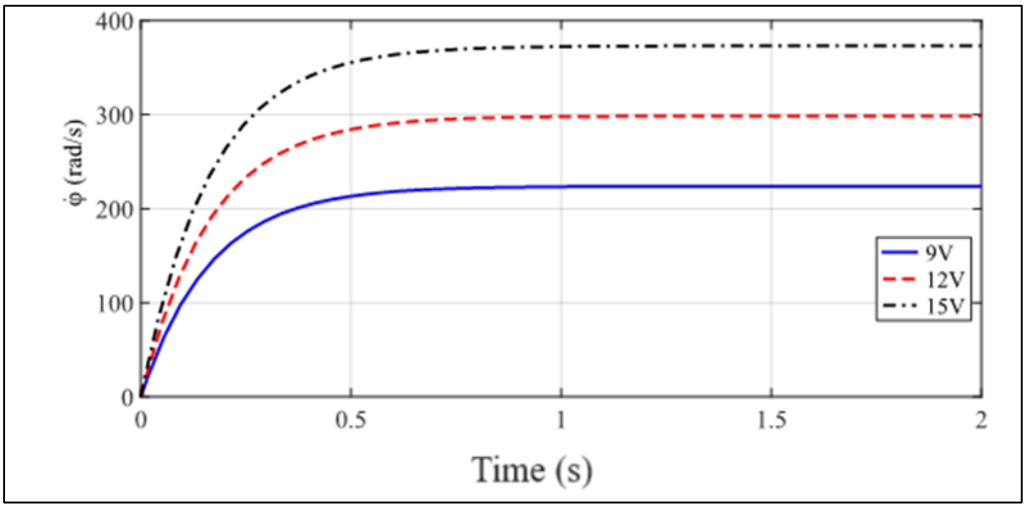

Figure 7 Engine speed graph

From Figure 6 and Figure 7, comments are made as follows:

- A motor that rotates evenly does not produce torque.
- The input voltage compared to the maximum torque generated by the motor and the steady speed of the motor have a linear relationship. Specifically, the greater the input voltage, the greater the maximum torque generated by the motor and the greater the steady speed.

4. Conclusion

The article has investigated the influence of the engine in a self-balancing two-wheeled vehicle model. Through investigation of the engine, it has been shown that if the engine rotates evenly, it will not be able to create torque to help the vehicle balance. At the same time, the voltage (when the torque is largest) and the speed (when the motor rotates stably) of the motor have a linear relationship. The research results of this article are the premise to survey other factors affecting the self-balancing electric motorbike model and the self-balancing electric motorbike control design.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they have no conflicts of interest

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