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A DC Motor Speed Control For Two Wheeled Vehicles With PWM

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ABSTRACT
In this modern era, the need for environmentally friendly vehicles is increasing, along with the increasing awareness of the importance of protecting the environment from pollution. One solution that is increasingly popular is the use of two-wheeled electric vehicles. These electric vehicles utilize DC motors as the main drive. In this system, controlling the speed of the DC motor is an important aspect to ensure efficient and responsive performance. This study examines the implementation of Pulse Width Modulation (PWM) as a method of controlling the speed of a DC motor in two-wheeled electric vehicles. PWM is a technique that allows control of the power received by the motor by adjusting the width of the digital signal pulse. With this method, the speed of the motor can be controlled precisely without losing significant power efficiency. This study focuses on the design and implementation of a speed control system using PWM, as well as testing the performance of the system on two-wheeled electric vehicles. The results of the study show that the use of PWM as a method of controlling the speed of a DC motor in two-wheeled electric vehicles is able to provide a fast and accurate response to the desired speed changes. This system is also proven to be energy efficient and able to reduce the heat generated by the motor, thereby extending the life of the motor. Thus, the use of PWM in the DC motor speed control system in two-wheeled electric vehicles is an effective and efficient solution to improve the performance and reliability of electric vehicles.

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INTRODUCTION

In recent decades, the transportation world has undergone a significant transformation, especially with the emergence of electric vehicles. One important aspect of this change is the introduction of electric two-wheelers, which have become an interesting trend in the automotive industry. The development of DC Motor Speed Control with Pulse Width Modulation (PWM) for electric two-wheelers is a major innovation in the automotive industry that aims to improve the efficiency, performance and durability of electric vehicles. By combining PWM technology with efficient DC motors, electric two-wheelers can provide a better driving experience, as well as a greater contribution to environmental sustainability. PWM offers an intelligent solution to control the power supplied to the DC motor by regulating the duration of the electric current signal pulse. This development brings several major advantages to electric two-wheelers, namely: high efficiency, responsiveness and precision, easier maintenance, reduced emissions and a more enjoyable driving experience.

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Literature Review

Initial Research on the Use of PWM in DC Motor Control

Early studies on the use of PWM in DC motor control were conducted in the 1970s. This research explored the potential of PWM techniques in controlling the speed of DC motors by varying the pulse width and period, allowing for finer and more accurate regulation. PWM works by dividing a certain period of time into several parts, during which the power signal is turned on or off to control the amount of power delivered to the motor. The wider the pulse given (on-time), the more power the motor receives. This allows motor speed control by changing the ratio between the time the signal is on and off. One of the advantages is high efficiency because the power delivered is only controlled by changing the pulse width, not by changing the voltage or current directly. This reduces energy waste in the form of heat. In addition, precise control allows for stable and accurate motor speed according to needs [1]. In the context of electric two-wheeled vehicles, DC motor speed control with PWM becomes very important. Accurate and responsive control is needed to provide a safe and comfortable driving experience. In addition, in electric vehicles, this technique can also be used to regulate energy regeneration during braking, which can improve overall efficiency [2].

DC Motor

DC (Direct Current) motor is a type of electric motor that converts direct current electrical energy into mechanical energy in the form of rotation or movement. This motor is very popular and is widely used in various applications, from children's toys to electric vehicles and industrial equipment. Here are some important aspects of DC motors [3].

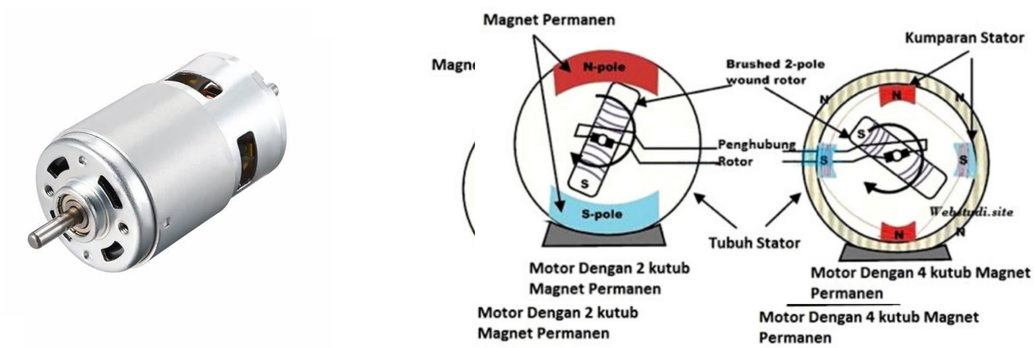

Figure 1. Physical form and construction of a DC motor

The speed of a DC motor can be controlled using several methods, including:

1. Voltage Regulation: Changes the input voltage to the motor to control its speed.
2. Pulse Width Modulation (PWM): A method that controls the power received by the motor by adjusting the pulse width of the digital signal, thus producing precise and efficient speed control.

DC Motor Applications

1. Electric Vehicles: As the main driver in electric scooters, electric cars, and electric bicycles.
2. Robotics: Used in robots to drive wheels and actuators.

DC Motor Equation

DC motors can be described through several equations that describe the relationship between voltage, current, speed, and torque. Here are some important equations used to understand and analyze the performance of DC motors:

Armature Voltage Equation

The total voltage applied to the armature terminals of a DC motor can be expressed by the following equation:

$$V = E + IaRa \quad (1)$$

Where :

V is the armature terminal voltage (volts).
E is the back electromotive force (back EMF) (volts).
It is the armature current (amperes).
Ra is the armature resistance (ohms).

Back EMF Equation

The back EMF (E) generated in a DC motor is proportional to the rotor rotational speed (ω) and the back EMF constant (kE):

$$E = kE \cdot \omega \quad (2)$$

Where:

E is back EMF (volts).
kE is the back EMF constant (volts/rad/s or volts/(rpm)).
ω is the rotor angular speed (rad/s or rpm).

Motor Speed Equation

By substituting the back EMF equation into the armature voltage equation, we get:

$$V = kE \cdot \omega + Ia \cdot Ra \quad (3)$$

By isolating the velocity (ω):

$$\omega = \frac{V - I_a R_a}{kE} \quad (4)$$

Motor Torque Equation

The torque (T) produced by a DC motor is proportional to the armature current (Ia) and the torque constant (kT):

$$T = kT \cdot I_a \quad (5)$$

Where:

T is torque (Nm).
kT is the torque constant (Nm/ampere or $kg \cdot m^2/s^2$).

Mechanical Power Equation

The mechanical power (Pm) produced by the motor can be expressed as:

$$Pm = T \cdot \omega \quad (6)$$

Motor Efficiency

The efficiency (η) of a DC motor can be calculated by comparing the mechanical output power to the electrical input power:

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$$\eta = \frac{P_m}{P_{input}} = \frac{T.\omega}{V.I_a} \quad (7)$$

The above equations provide a solid foundation for understanding and analyzing DC motor performance. Using these equations, we can calculate various important parameters such as voltage, current, speed, torque, and motor efficiency. This knowledge is very useful in the design and implementation of DC motor control systems, such as in electric vehicles, industrial equipment, and robotics applications.

DC Motor Characteristic Curve

The characteristic curves of a DC motor describe the relationship between various operating parameters such as speed, torque, current and efficiency. These curves are very important in understanding the performance of the motor under various load conditions and determining the most suitable application. Following are some of the main characteristic curves commonly used to analyze DC motors.

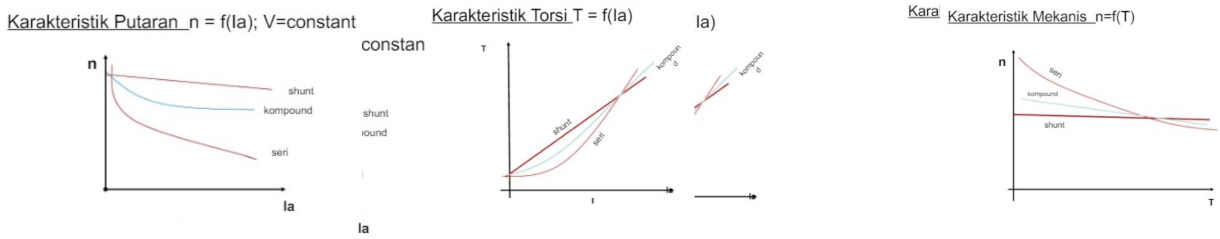

Figure 2. DC motor characteristic curve

The DC motor characteristic curves provide deep insight into how the motor will behave under various operating conditions. By understanding these curves, we can select the right motor for a particular application, optimize performance, and ensure the reliability and efficiency of the system used.

PULSE WIDTH MODULATION (PWM)

PWM works by dividing the time period into two main components: the period when the signal is on (on-time) and the period when the signal is off (off-time). The pulse width is the ratio of the time the signal is on to the time it is off in one period. By changing the pulse width, we change the percentage of time the signal is on, which in turn changes the average power delivered [5].

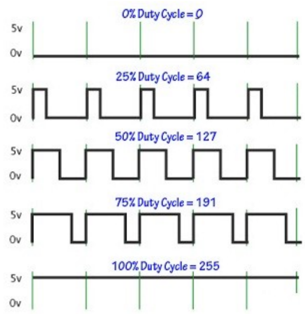

Figure 3. PWM waveform

One of the main advantages of PWM is its high energy efficiency. In many cases, such as motor speed control or LED lighting, the device will operate well even if it is supplied with lower power on average. By regulating the time at which the device is turned on, but keeping the voltage relatively constant, energy efficiency can be improved [6].

The basic equations for PWM involve several key concepts, namely period (T), frequency (f), and duty cycle (D).

1. Period (T)
   a. Period is the time required for one complete cycle of the PWM signal.
   b. The unit of period is seconds (s).
   c. The equation for the period is:

$$T=,1-f. \tag{8}$$

2. Frequency (f)
   a. Frequency is the number of PWM cycles per second.
   b. The unit of frequency is Hertz (Hz).
   c. The equation for frequency is:

$$f=,1-T. \tag{9}$$

Duty Cycle (D) :

1. Duty cycle is the percentage of a period in which the PWM signal is at a high level (ON).
2. Duty cycle is expressed in percentage (%).
3. The equation for duty cycle is:

$$D=,,,t\text{-}on.\text{-}T..\times 100\%$$

(10)

Where ton is the time in one period when the signal is at a high level.

In PWM applications, the duty cycle value determines how long the signal is at a high level in one period. For example, if the duty cycle is 50%, then the signal will be at a high level for half of the total period and at a low level the rest of the time.

PWM GENERATOR CIRCUIT

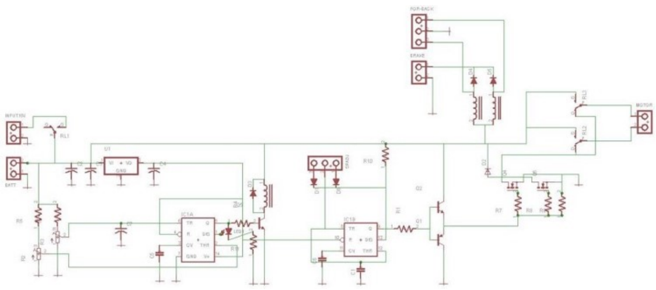

Figure 4. PWM generator circuit

The circuit above can provide an overview of the PWM technique on a DC motor driver. IC556 which is a dual 555 is set as an astable multivibrator with a fixed working frequency (fixed RC value) with the output given to a simple DC motor driver circuit with mosfet. The basic concept of PWM control using the circuit above lies in the addition of two diodes that control the charge and discharge process of the 0.1uF capacitor. The position of the 100K potentiometer lever connected to the two diodes will determine the charge or discharge time of the 0.1uF capacitor. The charge and discharge waveforms of the NE556

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astable multivibrator output as a PWM control for the DC motor driver in Figure 2.3. With this circuit, the DC motor control process can be smoother and more responsive.

RESEARCH METHODOLOGY

The research approach used is as follows: Problem Identification: This is the purpose of controlling the motor using PWM, for example, to increase energy efficiency, control motor speed, or reduce vibration. Literature Study: To understand the basic concept of PWM, the working principle of electric motors, and PWM applications in electric vehicles or other systems. PWM Circuit Design: Design a PWM circuit that meets the specifications of the electric motor and vehicle, including selecting the right electronic components. Simulation: Use simulation software such as MATLAB/Simulink or LTspice to test the performance of the PWM circuit in controlling motor speed and predicting energy efficiency. Implementation and Testing: Build the PWM circuit according to the design and test its performance on an electric motor. Record measurement data such as motor speed, current, voltage, and energy efficiency. Data Analysis: Analyze test data to evaluate the performance of the PWM circuit, including energy efficiency, speed response, and system stability. Conclusion and Recommendation: Conclusion based on the results of data analysis and discuss its implications for the use of PWM in motor control. And recommendations for further development

RESULTS

Data Analysis Methods

The data analysis methods used in this study are:

a. Correlation analysis to understand how strong the relationship is between two variables (for example, duty cycle and motor speed). Correlation can help you determine if there is a linear relationship between the variables. Duty cycle is the ratio of the time a signal is active to the total time period. In the context of DC motors, duty cycle is generally associated with PWM (Pulse Width Modulation) control, which is used to regulate motor speed [9].

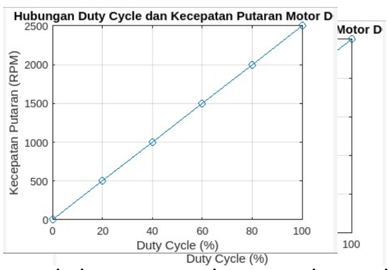

Figure 5. Correlation graph between duty cycle and DC motor rotation

The results of this test are presented in table 1.

Table 1. Results of DC Motor Voltage vs Speed Test

No	Voltage (V)	Rotation (rpm)
1	3	0
2	4	350
3	5	800

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No	Voltage (V)	Rotation (rpm)
4	6	945
5	7	1100
6	8	1200
7	9	1375
8	10	1400
9	11	1450
10	12	1500

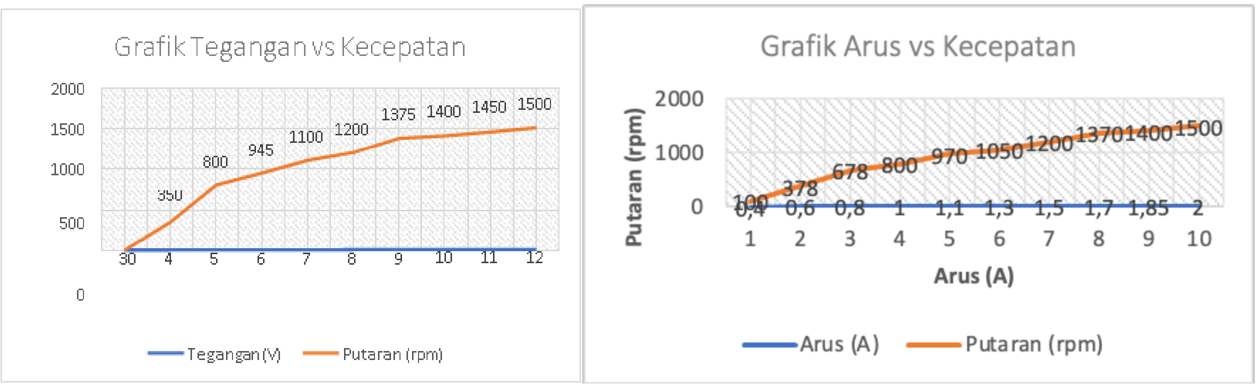

Figure 6. Voltage vs. Speed and Current vs. Speed Graphs

Discussion

From the above test, it can be seen the correlation between the variation of input voltage and the variation of DC motor speed. The higher the voltage given, the faster the DC motor will rotate. Likewise, the input current is directly proportional to the input voltage given to the DC motor. This can be seen in the graph in Figure 6. So it can be assessed that this control system has a linear relationship between input voltage and input current with the speed of the DC motor.

CONCLUSION

The conclusions of this research are: The designed DC motor speed control system is working as desired. There is a linear correlation between input voltage and motor rotation speed. Likewise, the correlation between input current and motor speed.

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