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STUDY THE EFFECT OF WHEEL RADIUS ON THE ELECTRIC MOTORBIKE PERFORMANCE THROUGH A SIMULATION MODEL

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ABSTRACT

The purpose of this research is to study how wheel radius affects the Electric Motorbike's performance. Based on mathematical models and the MATLAB SIMULINK software, an electric motorcycle simulation model, including a dynamic model and a battery model, was created to achieve this goal. The simulation model is used to determine the speed, thrust torque, and power consumption characteristics with changing wheel radius. The simulation results show that when changing the wheel radius from 0.1 m to 0.25 m, the maximum speed increases from 23 to 52 km/h, the travel distance increases from 400 to 850 m after 60 seconds of simulation time, and the battery voltage decreases from 59.9 to 57.7 V while the engine power consumption increases.

Keywords: wheel radius, electric motorbike, simulation model, battery model.

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1. INTRODUCTION

Because fossil fuels have a long renewable process, their availability is decreasing [1-2]. The increase in demand for fossil fuels has increased researchers' interest in discovering renewable and clean energy sources. The primary goals of early applications of reducing dependence on gasoline, increasing efficiency, and saving fuel have become the focus of researchers worldwide [3-5]. One promising choice is electric vehicles (EVs), which have significant advantages such as increased energy efficiency, reduced harmful emissions, and reduced noise compared to internal combustion engines [6–7]. One potential electric vehicle is the electric motorcycle [8], which is not only suitable for traveling short distances on diverse terrains but is also convenient compared to other electric vehicles given its price, maintenance, and service costs. reasonable correction [9-13].

Behzad Asaei et al. [14] investigated the performance, fuel consumption, and emissions of a hybrid electric motorcycle equipped with a brushless DC motor integrated into the front wheel. The simulation results show that the improved motorcycle performance achieves 16.7 and 29.3% improvements in acceleration from 0 to 60 km/h and 0 to 100 km/h, respectively. Fuel consumption is also reduced by 28% compared to traditional motorcycles. During this cycle, pollution decreased by 29%, 30%, and 21%, respectively. If the motor is downsized to a smaller type and an optimally sized wheel motor is used, further improvements can be made. Joerg Dieter Weigl and Hamdani Saidi [15] have proposed an alternative to deal with noise and air pollution. Design a prototype and build a motorcycle powered by a zero-emission hydrogen fuel cell with very low noise compared to existing motorcycles.

Cossalter et al. [16] studied the effect of tire characteristics on the stability of the vehicle when running straight. This analysis demonstrates that the characteristics of the front tires have a significant effect on stability, while the characteristics of the rear tires have a small effect. Stability differences are more relevant at low speeds, while at high speeds they tend to disappear due to the great importance of the gyroscope effect. However, it should be noted that axial inertia is also a tire characteristic. It was found that an increase in the diagonal size of the front tire reduced roll and stability when rocking. The presence of torque is important to increase the stability of the overturn at low speeds, while it has the opposite effect on weaving. Self-aligning torque reduces oscillation stability at low speeds and increases it at high speeds. Pneumatic trails were found to be slightly unstable on overturns, while mechanical trails tended to be significantly stable on overturns. The change in the lateral stiffness of the rear tire has a slight effect on the stability of the motorcycle, while an increase in the stiffness of the front tire will increase the stability of the swing.

Finally, through a brief summary of previous studies in the field of electric motorcycles, we find that most of the previous studies have focused on the study and analysis of energy consumption. Very few studies have examined the dynamism and efficiency of electric motorcycles through the parameters of wheel radius using simulation software. This paper studies in detail the influence of key parameters, including the operating and structural parameters of the wheel radius, on the working efficiency of electric motorcycles.

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2. METHODOLOGY

2.1 Input Parameters

The input parameters include motorcycle mass, rider mass, wheel radius, front bumper area, and gear ratio, which greatly affect the operation of an electric motorcycle. This study will learn about how changing the transmission ratio affects the speed, distance, and power of electric motorcycles.

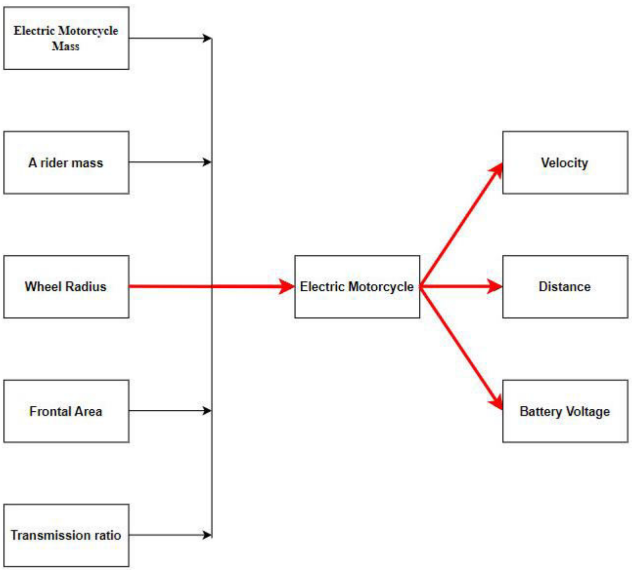

Figure-1. The input parameters effect on vehicle performance.

2.2 Electric Motorbike Model

The free-body diagram of an electric motorcycle is depicted in Figure-2, which is the basis for simulating the dynamics of an electric motorcycle.

Newton's second law of the acceleration of an object can be described by:

$$F = m\frac{dv}{dt} = ma \tag{1}$$

Apply Newton's second law to the motion of an electric motorcycle, which is described by:

$$F_{pf} - \left(F_{sf} + F_{wf} + F_{rf}\right) = M\frac{d^2x}{dt^2} = Ma \tag{2}$$

Where: F_{pf} the propulsion forceF_{sf} the slope resistance force. $F_{sf} = MgC_s$, F_{wf} the wind resistance force, $F_{wf} = \frac{1}{2} A_{fa}C_a\rho(v_w + v_{EM})^2$, F_{rf} the rolling resistance force $F_{rf} = gMC_{rr}\cos a$

A_{fa} : Frontage area (m^2)
C_a : Aerodynamic drag coefficient
ρ : Air density, kg/m^3
v_w : Wind speed, km/h
v_{EM} : Electric motorcycle speed, km/h
g : Gravity force, m/s^2
C_{rr} : Rolling resistance coefficient

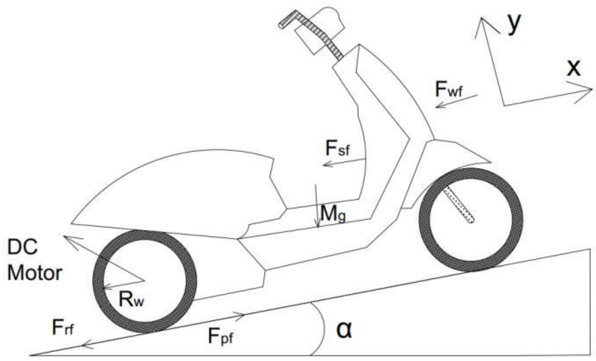

Figure-2. Diagram of forces acting on the vehicle.

A DC motor is used to power the electric motorcycle and is mounted on the rear wheel, as shown in Figure-3. When the electric scooter is in operation, the DC motor uses electricity from the Li-ion battery as the power source. Energy source to generate thrust; torque can be calculated as follows:

$$T_p = F_{pf}R_w \tag{3}$$

Where: T_p propulsion torque, R_w wheel radius.

$$T_p = \gamma T_m \tag{4}$$

Where γ transmission ratio, T_m Electric motor Torque (Nm)

By combining equations (3) and (4) the torque can be recalculated as follows:

$$F_{pf}.R_w = \gamma T_m \tag{5}$$

Figure-3 depicts the continuous-time electromechanical equation of a separately excited DC motor circuit.

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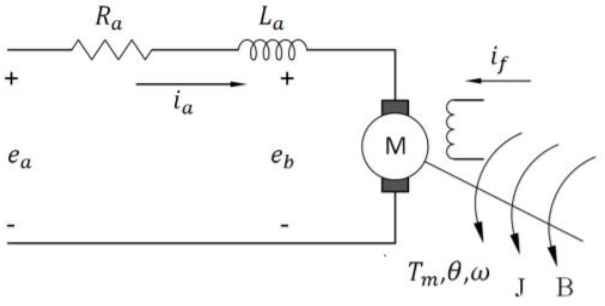

Figure-3. Equivalent circuit of DC motor.

From Figure-3, the electromechanical equations related to the excited DC motor circuit are described by:

$$L_a \frac{di_a}{dt} + i_a R_a + E_c = K_a u \quad (6)$$

$$\int \frac{dw_m}{dt} + B_1 w_m = T_e - T_m \quad (7)$$

Where

L_a	: Inductance of the motor (H)
K_b	: Electromotive constant
K_a	: Motor gain
u	: Input voltage
J	: Motor moment of inertia (N.m)
T_e	: Torque generated
E_c	: EMF back side
$B1$	: Coefficient of friction of the electric motor
T_m	: The motor torque (N.m).
R_a	: Motor resistance
t	: Time (s)

The variable DC motor is the armature current, and the mechanical variable is the speed. E_{mf} return (E_c) is proportional to speed, the torque generated (T_e) is proportional to armature current.

$$E_c = K_b w_m \quad (8)$$

$$T_c = K_b i_a \quad (9)$$

By combining equations (6)-(9), we can obtain Equations (10) and (11), which are the electrical behavior and mechanical behavior of a DC motor, respectively [23, 24].

$$L_a \frac{di_a}{dt} + i_a R_a + R_b w_m = K_a u \quad (10)$$

$$\int \frac{dw_m}{dt} + B_1 w_m + T_m = K_b i_a \quad (11)$$

By combining equation (5) - (11), the propulsive force can be calculated as follows:

$$F_{pf} = \frac{1}{R_w}\left[\frac{K_b K_a}{R_a} u - \frac{K_b L_a di_a}{R_a dt} - \int \frac{dw_m}{dt} - \left(B_1 + \frac{K_a K_b}{R_m}\right) w_m\right] \quad (12)$$

2.3 Electric Motorbike's Performance Model

Total power is used to help riders and electric scooters overcome air resistance, gradients and rolling friction.

$$P_{total} = P_{air} + P_{slope} + P_{friction} \quad (13)$$

Here, P_{air} is the power consumed to overcome air resistance. It can be calculated as below equation:

$$P_{air} = \frac{A_{fa} C_a \rho (v_w + v_{EM})^2}{2} v_{EM} \quad (14)$$

The power consumed to overcome the slope resistance (P_{slope}) can be calculated by the following formula:

$$P_{slope} = MgC_s v_{EM} \quad (15)$$

The power required to overcome rolling friction can be calculated by the formula below:

$$P_{friction} = gMC_{rr} \cos a v_{EM} \quad (16)$$

2.4 Battery Model

The electric scooter is equipped with a Li-Ion battery, which is used as a power supply for the DC motor. When the Li-Ion battery discharges, power is transferred to the DC motor during electric motorcycle operation. When a Li-Ion battery discharges, the battery voltage can be written as [25]:

$$v_b = E_0 - \frac{KQ}{Q - i_{(t)}}(i) - R.i + Ae^{(-B.i(t))} - \frac{KQ}{Q - i_{(t)}} i^* \quad (17)$$

Where

E_0	: Constant voltage of battery (V)
K	: Polarization Constant (V/Ah)
Q	: Battery capacity (Ah)
R	: Internal resistance
i	: Current (A)

The simulation case studies with various wheel radius of the electric scooter in this research are presented in Table-1.

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Table-1. Wheel radius cases study.

Speed	Wheel radius (m)
Case 1	0.1
Case 2	0.12
Case 3	0.15
Case 4	0.2
Case 5	0.25

3. RESULTS AND DISCUSSIONS

From the mathematical model of electric motorcycles, Matlab/Simulink simulates the working characteristics of electric motorcycles. A list of some of the modules used in the simulation process.

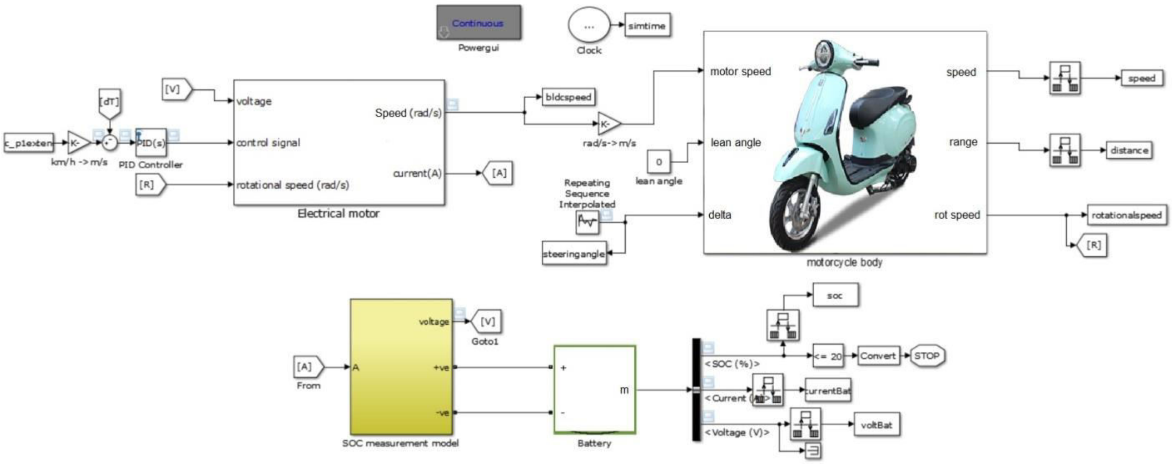
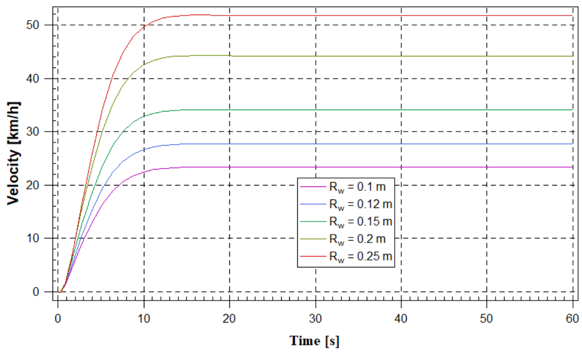


Figure-4. Electric motorbike model.

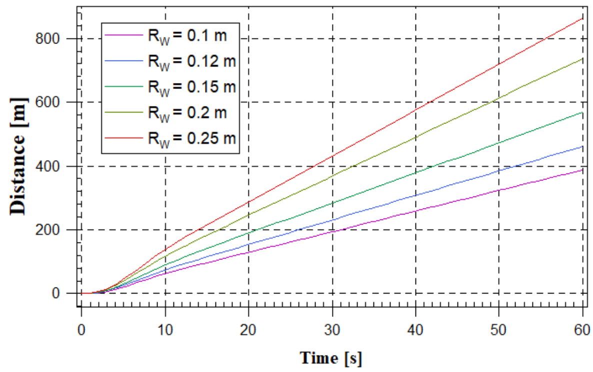
Table-2. Vehicle specification.

Testing Vehicle specification	
Weight	90kg
Saddle height	1260 mm
Distance travelled	60-70 km/ charge
Max speed	40-50km/h
Wheel	10" / 10"
Vehicle size (DxRxC)	1750 x 710 x 1110 mm
Driver's meter	LCD Led Backlit 4.5"
Electric motor	1000w

Figure-5 shows the simulation results for speed, distance travelled, power consumed and thrust torque as functions of gear ratio. Simulation conditions include: the rider has a mass of 78 kg; the electric motorcycle weighs 90 kg, a wheel radius of 0.215 m, a wind speed of 0 km/h and a slope of 0%.



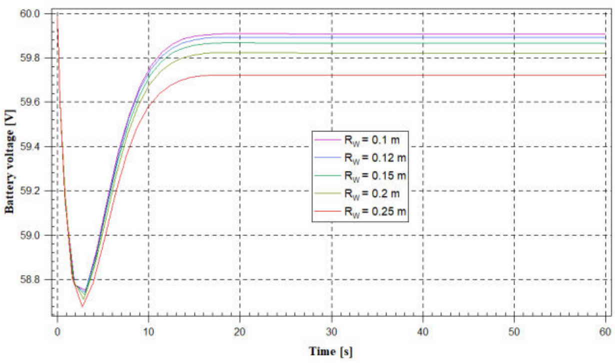
a)



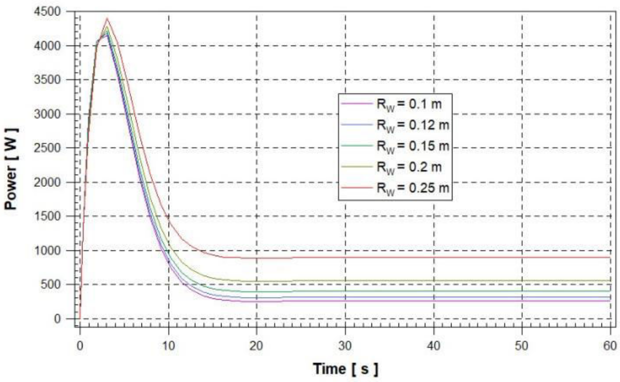
b)

Figure-5a and 5b. Show the effect of gear ratios on the distance travelled and velocity.

As the wheel radius increases from 0.1 to 0.25 m, the maximum speed increases from 23 to 52 km/h. This can be explained by the fact that the increase in wheel radius leads to an increase in rotational inertia. The increase in velocity leads to an increase in the distance travelled from 400 to 850 m after 60 second of simulation time as a result.



c)



d)

Figure-6. Effect of wheel radius on a) velocity, b) distance, c) battery voltage, d) engine power.

The increased wheel radius led to an increase in the required propulsion torque, and velocity led to an increased load on the motor, so the energy demand for the motor is high, thereby increasing electricity consumption. This can be seen as the decrease in battery voltage (Figure 6c) and increase in engine power consumption (Figure-6d).

4. CONCLUSIONS

According to the findings, Matlab and Simulink mathematical models and simulations are among the most effective tools for research and application in practice with this model, it can be seen that the dynamic performance and power consumption of an electric motorcycle can be optimized by adjusting the input parameters of the wheel radius. Research results show that when increasing the wheel radius from 0.1 to 0.25, the maximum speed increases from 23 to 52 km/h, the travel distance increase from 400 to 850 m after 60 second of simulation time, and the power consumption increases.

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