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Analysis of Two In-Wheeled DC Motor for Autonomous Electric Vehicle: Simulation and Experiment

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ABSTRACT –A simulation model of the electric vehicle is important to test a proposed theory since implementing it in real life could be costly and dangerous since it is susceptible to failure. This paper focuses on the development of an electric vehicle model, which represents a real vehicle. The simulation model is developed by integrating combined vehicle dynamic model, Dugoff's tire model and DC motor model. The result is then compared with a small-scale electric vehicle. The result shows that the simulation model developed depicts accurately the yaw rate, lateral acceleration and longitudinal velocity when compared with the test vehicle.

1. INTRODUCTION

Development of autonomous vehicle are widely covered by many researchers[1,2]. A breakthrough in electric vehicles (EV) has further enhanced the development of autonomous vehicles, as the electric motors used are easy to control compared to conventional vehicles[3]. A more prominent development is the in-wheel motors, which substitutes the single central motor system. According M.H.Bin Peeie et al.[3], the in-wheel motors are the future of EV's due to its compact size and energy efficiency. There are two main type of in-wheel motor configuration for EVs, namely four or two in-wheel motors. Due to the complexity of controlling the four in-wheel motors, this paper is crafted based on the two in-wheeled EV at the rear tires.

Developing an efficient EV requires various test to be conducted. However, it is costly to perform modification on real vehicles, as it can be costly and dangerous. Example of such test is identifying effect of vehicle vibration on human brain and skull[6]. Thus, a simulation model is widely used in order to test these systems before implementing them in real vehicles. Many available simulation software are either expensive or does not consider a complete vehicle model that considers many factors. Vehicle dynamic is an important criterion in simulating a vehicle virtually. There are two type of vehicle dynamic, lateral and longitudinal model[4]. However, when using lateral and longitudinal model together a combined model is required[5]. The objective of this paper is to discuss the vehicle model developed based on combined vehicle dynamics, Dugoff's tire model, DC motor model, variation of normal force due to mass transfer and variation of tire-road friction coefficient due to vehicle-wheel velocity slip ratio. The result is compared with the experimental data that is obtained from the test vehicle.

2. METHODOLOGY

2.1 Simulation Setup

The simulation model is developed based on the vehicle model proposed by K.Baarath et al.[5]. The Figure 1 depicts the simulation model flow.

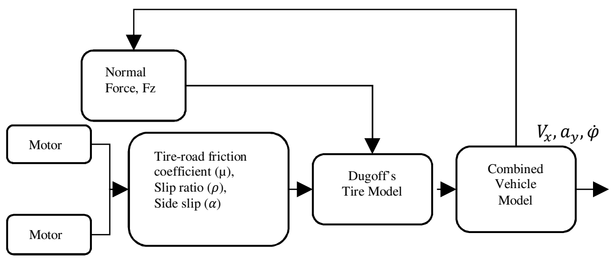

Figure 1 Representation of the simulation model.

The simulation is conducted in Matlab software. The parameters used are shown in Table 1.

Table 1 Vehicle parameters used[5].

Symbol	Value	Units
l_f	1.4	*m*
l_r	1.4	*m*
$C_{\alpha f}$	2000	*N/rad*
$C_{\alpha r}$	2612.62	*N/rad*
C_{σ}	3000	*N/m*^{3}
k	1=dry asphalt	-
r_{eff}	0.23	*m*
g	9.1=81	*m/s*^{2}
h_c	0.75	*m*
l_w	0.9	*m*
m_f	650	*kg*
m_r	980	*kg*
I_w	1.53	*kgm*^{2}
I_x	1470	*kgm*^{2}

2.2 Experimental Setup

The experiment is conducted using a small-scale electric vehicle. Figure 2 shows the electric vehicle used in the experiment. A gyroscope is placed at the center of the vehicle to sense the yaw rate, velocity and lateral acceleration of the vehicle.

Figure 2 Small-scale electric vehicle used.

3. RESULTS & DISCUSSIONS

In the simulation, the vehicle is set to run at 9km/h, same as the test condition of the test vehicle. The steering input is given similar to the steering of the test vehicle in order to validate the model developed. The result in Figure 3 shows the longitudinal velocity of the vehicle. The experimental graph shows a large decrease in velocity at 40s. This is due to the braking action in the test car when turning. However, in the simulated result the velocity does not experience the decrease in velocity since the braking is not considered in the model. At t=56s when the turning maneuver is applied the longitudinal velocity of the vehicle decreases around 0.5 km/h which is similar to the simulated result as observed.

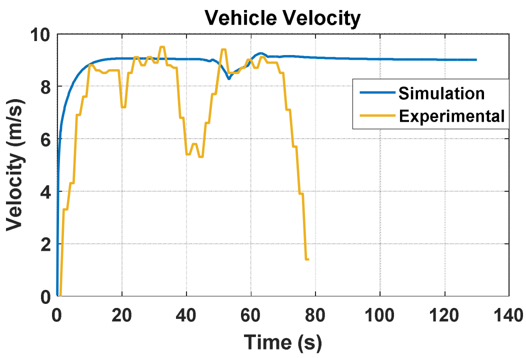

Figure 3 Comparison of longitudinal velocity of experimental and simulated result.

Figure 4 shows the yaw rate produced when the vehicle is maneuvered. The graph shows that both the simulated and experimental result is similar. The slight difference between the experimental and simulation is due to the noise on the sensor.

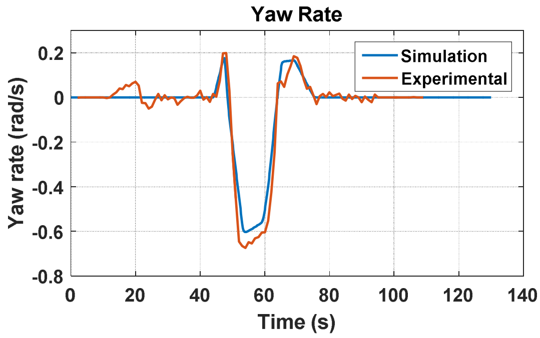

Figure 4 Comparison of yaw rate of experimental and simulated result.

4. CONCLUSIONS & RECOMMENDATIONS

The vehicle model developed is able to provide accurate representation of vehicle motion when steering input is given. Based on the result, there is difference in vehicle velocity since the braking force is not considered in the model. However, ignoring the braking, the simulation model is suitable to use to represent a vehicle and produce accurate results.

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