

Simulation-Based Engineering Lab
University of Wisconsin-Madison

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Modeling linear DC motor in Chrono rover models

Jason Zhou, Wei Hu, Radu Serban and Dan Negrut

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Abstract

This Technical Report records the implementation details of the linear DC motor, which are used in VIPER and Curiosity rover models in Chrono.

Keywords:

Contents

1	Introduction	3
2	Design and Implementation Details	3
3	Flaws and Future Work	6

List of Figures

1	DC Motor Mechanical Components Layout	3
2	DC Motor Torque-Rotational Speed Map at $T_{stall} = 500$ N-m and $\omega_{noload} = \pi$ rad/s	4
3	Simulation Set Up to Investigate Reaction Torque and Rotational Speed of the Left Front Rover Wheel	5
4	Comparison Between DC Motor and Constant Rotation Motor's Behavior . .	5

1 Introduction

In previous simulations, we have used a constant rotational speed to define the behavior of the motor. In some cases, we have observed extremely large torque or force applied on rover wheels to maintain this rotational speed. Enforcing this constraint might not be realistic as the actual rotational speed of the motor changes if the resistant torque applied on wheel changes. Therefore, a basic DC Electrical Motor has been modeled and incorporated into the VIPER and Curiosity-class rovers to simulate the behavior of a DC electrical motor.

2 Design and Implementation Details

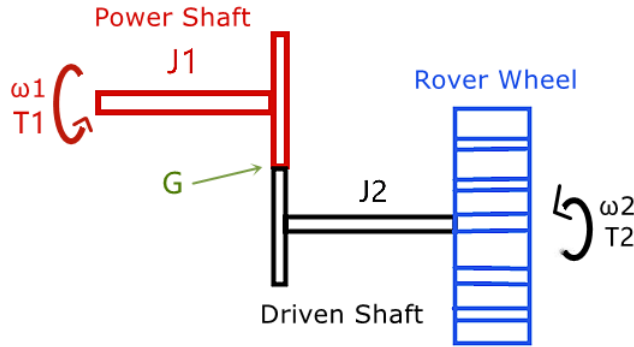


Figure 1: DC Motor Mechanical Components Layout

The mechanical components of the motor is shown in Figure 1. For each motor, a power shaft is connected to a driven shaft through a gear-pinion system, which has a gear ratio of G . The rover wheel is rigidly connected to the driven shaft. A torque *Torque* T_1 is applied on the power shaft. Through the gear-pinion system, torque transferred to the rover wheel satisfies the equation

$$T_2 = -T_1 G . \tag{1}$$

The DC motor control follows a negative linear relationship between the torque applied on the power shaft T_1 and the rotational speed of the Driven Shaft ω_2 . This relationship is determined by two parameters - motor stall torque T_{stall} and motor no-load speed ω_{noload} . For example, if the stall torque T_{stall} is set to 500 N-m, and the no-load speed ω_{noload} is set to $\pi \text{ rad/s}$, the motor torque-rotational speed map is shown in Figure 2. The direction of ω_1 and ω_2 are opposite, on the unobstructed motor driven direction as shown in Figure 1

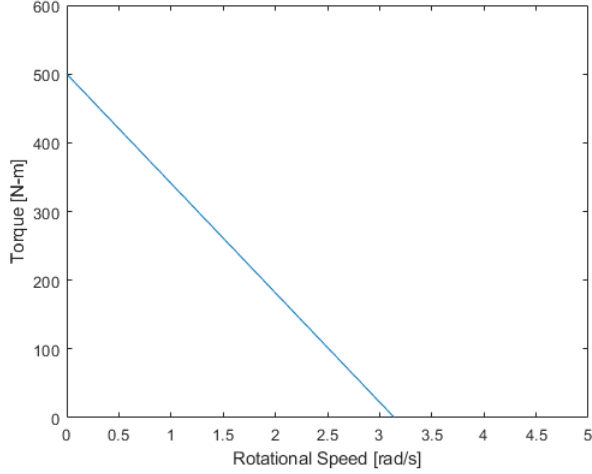


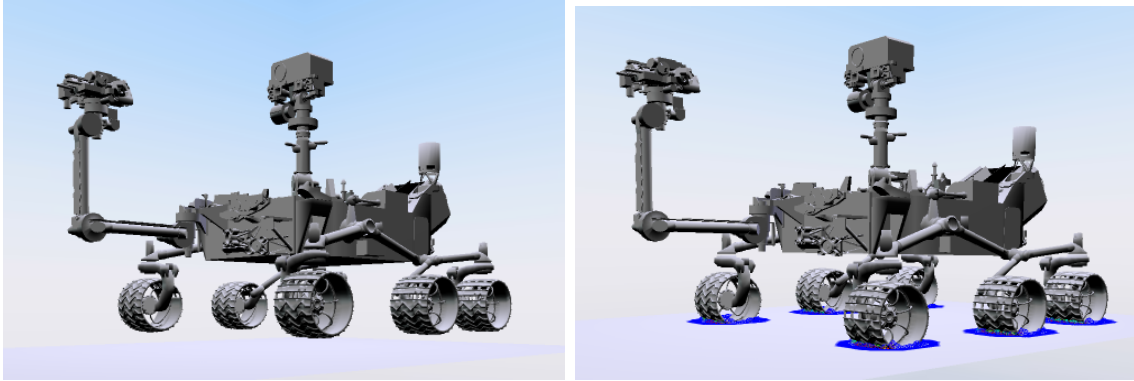
Figure 2: DC Motor Torque-Rotational Speed Map at $T_{stall} = 500$ N-m and $\omega_{noload} = \pi$ rad/s

Therefore, the torque applied on the power shaft at next time step $t + 1$, $T_{1,t+1}$, depends on the rotational speed of the driven shaft at the current time step T , $\omega_{2,t}$. The $T_{1,t+1}$ is computed at every time step using equation 2.

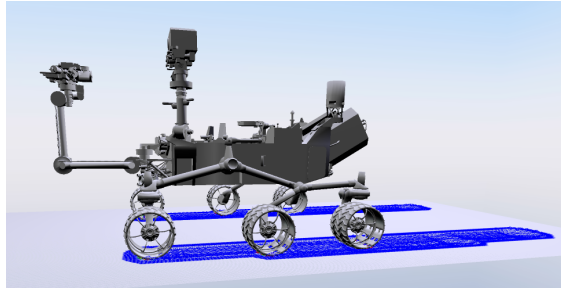
$$\begin{cases} T_{1,t+1} = \frac{\omega_{noload} - \omega_{2,t}}{\omega_{noload}} T_{stall}, & \text{if } 0 \leq \omega_{2,t} \leq \omega_{noload} \\ 0, & \text{if } \omega_{2,t} > \omega_{noload} \\ T_{stall}, & \text{if } \omega_{2,t} < 0 \end{cases} \quad (2)$$

Comparisons between the previous constant rotational speed motor and the linear DC motor model have been conducted on flat SCM Terrain. The Curiosity rover was dropped from a 1 m height above the terrain and starts accelerating. The reaction torque applied by the SCM Terrain and the rotational speed of the left-front wheel of the rover are recorded. In the constant rotational speed motor case, the default rotational speed of the motor is π rad/s, and in the DC motor case, the stall torque T_{stall} has been set to 500 N-m, and no-load rotational speed has been set to π rad/s. Figure 3 shows the simulation snapshots of this simple set up.

The result of the comparison is shown in Figure 4. Even though the testing scenario is simple, it tests the motor behaviors under the situations of reacting to sudden obstructive force and acceleration. The DC motor simulation results provide a more realistic behavior, taking into consideration the initial motor acceleration during start-up and interaction with the obstructive forces applied by the terrain.

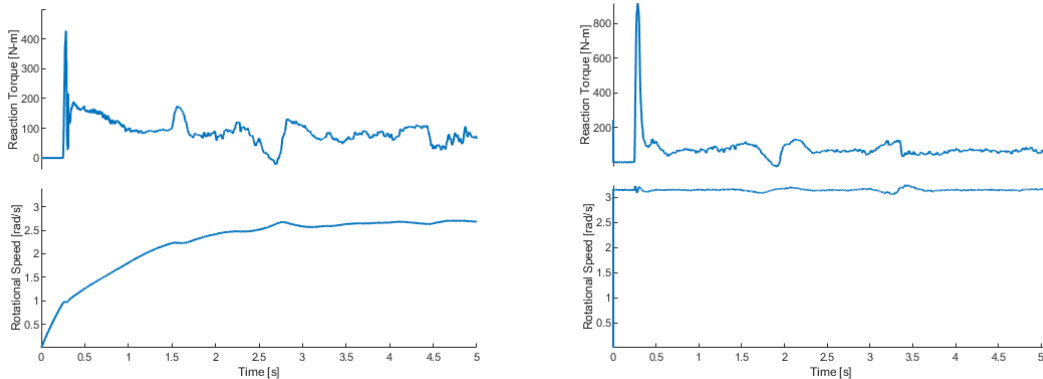


(a) At $t=0$, the rover is dropped from 0.3 m above the SCM terrain (b) At approximately $t=0.2$, the rover touched down and starts accelerating



(c) At the end of simulation, the rover reached a constant moving speed after acceleration

Figure 3: Simulation Set Up to Investigate Reaction Torque and Rotational Speed of the Left Front Rover Wheel



(a) DC Motor's Rotational Speed and Reaction Torque in $t=5s$ (b) Constant Rotational Speed Motor's Rotational Speed and Reaction Torque in $t=5s$

Figure 4: Comparison Between DC Motor and Constant Rotation Motor's Behavior

3 Flaws and Future Work

The current implementation only allows the users to define a linear DC-motor Torque vs Rotational Speed map. However, realistically speaking, the DC-motor behavior is generally defined as a Torque vs Rotational Speed curve, which is not necessarily linear. Therefore, in the near future, the implementation should be improved and able to accept a DC curve definition.