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小型二輪月面探査機の走行性能に及ぼす車輪回転数の影響

Effect of Wheel Rotation Speed on the Running Performance of a Small Two-Wheeled Lunar Rover

大谷岳斗 [1], 森裕人 [2], 渡辺公貴 [2], 田中和人 [2], 川口正隆 [2],
Yamato OTANI[1], Hiroto MORI[2], Kimitaka WATANABE[2], Kazuto TANAKA[2] and Masataka KAWAGUCHI[2]
[1] 同志社大学大学院，Doshisha University
[2] 同志社大学，Doshisha University

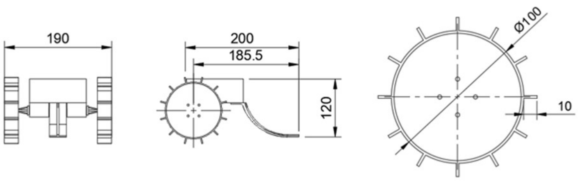
1. Introduction

In recent years, unmanned exploration of the Moon using rovers has been attracting attention because of the hazardous environment for human beings at the Moon. The problem with small two-wheeled rovers, which can reduce development costs, is that regolith on the lunar surface causes them to become stuck[1)] , a condition that prevents them from moving forward. This study aims to reduce the amount of having rovers getting stuck by adjusting the rotation speed of the wheels of a small two-wheeled lunar rover and to run with low power consumption. The optimal speed of a small two-wheeled rover that can run with low power consumption will be proposed.

2. Experimental methods

2.1. Creation of a small two-wheeled rover

Figure. 1 shows a drawing of a small two-wheeled rover body and circular wheels. In this study, a 3D printer (Raise3D Pro3 Plus, JAPAN 3D PRINTER) was used to create the body and wheels in layers. ABS resin (RAISE 3D) was used as the material. Two servo motors (XC-330-M288-T, DYNAMIXEL, ROBOTIS) were controlled by a board computer (SPRESENSE, SONY) to control the phase and speed of the left and right wheels. The circular wheel was 100 mm in diameter and 25 mm thick, with 12 lugs of 10 mm long mounted at equal intervals on the outside of the wheel.



(a)Two-wheeled rover (b)Circular

Figure 1. Rover and wheel blueprints

2.2. Running tests

In this study, the created rover was driven on soil covered with a lunar soil simulant (FJS-1, Shimizu Corporation) as a substitute for regolith. The wheel rotation speed was adjusted in 2 min^{-1} increments from 6 min^{-1} to 14 min^{-1}. Three parameters were used to evaluate the running performance: running time, energy consumption during running and slip rate. The slip rate was calculated using the following equation, where V_ω is the wheel's running speed, γ is the wheel's circumference and ω is the angular velocity.

$$\lambda = 1 - \frac{V_\omega}{r\omega} : Driving(r\omega \geq V_\omega) \tag{1}$$

$$\lambda = 1 - \frac{r\omega}{V_\omega} : Breaking(V_\omega \geq r\omega) \tag{2}$$

The running distance was set to 700 mm and the inclination angle was set to 0 degrees. The shear strength at a depth of 40 mm was measured using a vane shear test apparatus (FTD2CN-5, Nishinihon Shikenki Co., Ltd.） The average shear strength of the test area before driving was set to 0.4 ± 0.05 by using a leveling machine and a flat plate.

3. Results

Figure 2 shows the results of the running test. The running time and energy consumption decreased as the rotation speed increased, but the rotation speed and energy consumption increased at 14 min-1. Table 1 shows the shear strength of the soil after running. The shear strength decreased as the rotation speed increased.

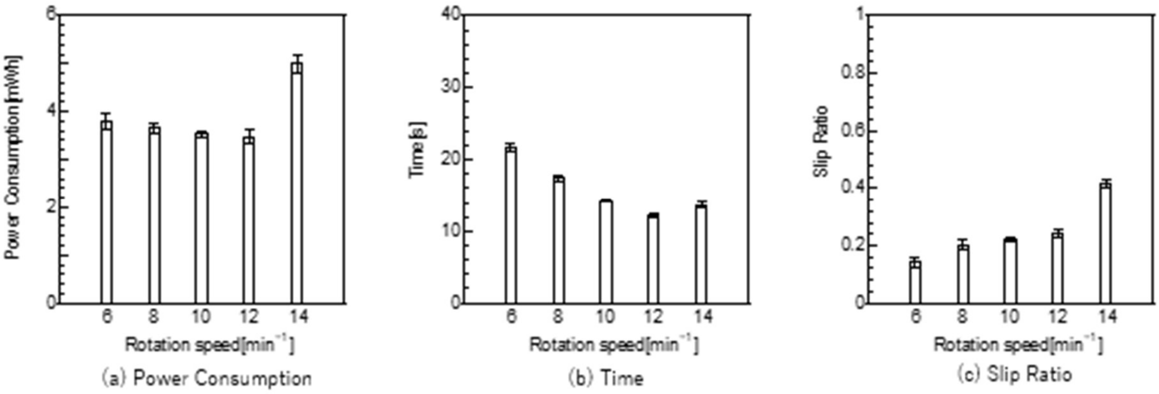


Figure 3. Runnning test results

Table 1. Shear strength and trend of soil in ruts after driving

Rotation [min^{-1}]	Track [cNm]	Tendency
6	0.53	Increase
8	0.52	Increase
10	0.49	Increase
12	0.42	Increase
14	0.34	Decrease

4. Discussion

It has been reported that the main propulsive force for wheeled rovers in soft ground is the passive pressure of the wheel lugs[1)]. The passive pressure is related to the soil density, which increases as the soil density increases. It is reported that as speed increases, sand under the wheel escapes outward and the soil cannot be compacted[2)] . Therefore, as velocity increases, wheel sinkage increases. It is also reported that the density increases with soil depth[3)] , and although the sinkage increases as the rotation speed increases, it converges to a constant value as the density increases. Therefore, it is considered that as the rotation speed increases, the running time decreases, resulting in lower energy consumption. In addition, it is thought that above a certain rotation speed, sufficient passive pressure could not be obtained, resulting in a decrease in running performance.

5. Conclusion

A small two-wheeled rover was created and its running performance was evaluated by adjusting wheel rotation speed. Increasing wheel rotation speed shortens the running time and enables running with low power consumption, but above a certain number of rotations, sufficient passive pressure cannot be obtained, and running performance deteriorates.

References

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