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四輪小型月面探査機の走行性能に及ぼす車輪位相の影響

Effect of Wheel Phase on Running Performance of a Small Four-Wheeled Lunar Rover

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1. Introduction

In recent years, space exploration has been actively pursued to elucidate the origins of the universe and to solve social problems. The lunar environment is covered with regolith, particles and pieces of rock-derived.[1)] Lunar rovers are methods of exploring such environments. Rovers are classified according to size and operating mechanism, small wheeled lunar rovers with simple structure and light weight are attracting attention to reduce development and transportation costs. In two-wheeled small lunar rovers, wheel phase control has been reported to improve the running performance[2)]. However, no research has been conducted on wheel phase control for four-wheeled small lunar rovers. Therefore, this study aims to clarify the effect of wheel phase control on the running performance of a small four-wheeled lunar rover.

2. Experiment method

The main body fabricated using the 3D printer Raise3D Pro (Raise3D) is shown in Figure 1. The length of the rover body, the width and the height excluding the wheels are 230 mm, 81 mm and 72 mm, respectively. A single double shaft DC geared motor (JGY-370, 6 V, 10 RPM, Tangxiaonei) is used to synchronise the phases in the rotation of all four wheels. In addition, two gearboxes (BS65T-001, Kyoiku Gear) are used to transfer the power of the DC geared motor to the four wheels, changing the direction of rotation by 90° to achieve four-wheel drive. The used wheels are an elliptical column wheel, a triangular column wheel and a three-bladed wheel as shown in Figure 2. The wheel thicknesses are all 30 mm and the phases of the front and rear wheels are shifted using the shafts shown in Figure 3. When the front and rear wheels are in the same phase, they are referred as in same phase; when the front and rear wheels are 90° out of phase for the elliptical column wheel and 60° out of phase for the triangular column wheel and three-bladed wheel, they are referred as in opposite phase. Running tests are carried out on a 1:1 mixture of silica sand No. 5 (Takeori Kohnetsu) with a particle size of 0.3 ~ 0.8 mm and silica sand No. 6 (Takeori Kohnetsu) with a particle size of 0.2 ~ 0.3 mm, with a running distance of 1000 mm and slope angles of 10°, 15°, 20°, 25° and 30°. For the running tests, running time and energy consumption are used to evaluate running performance, and the trajectories of running are analysed using Image J by videotaping from the side view of 30° slope climb.

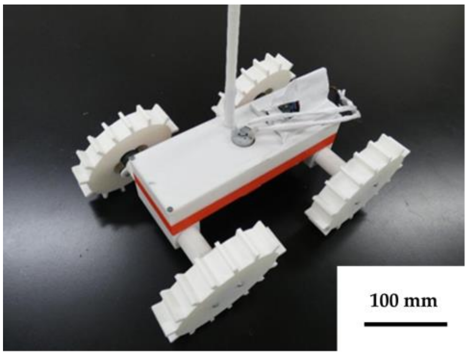
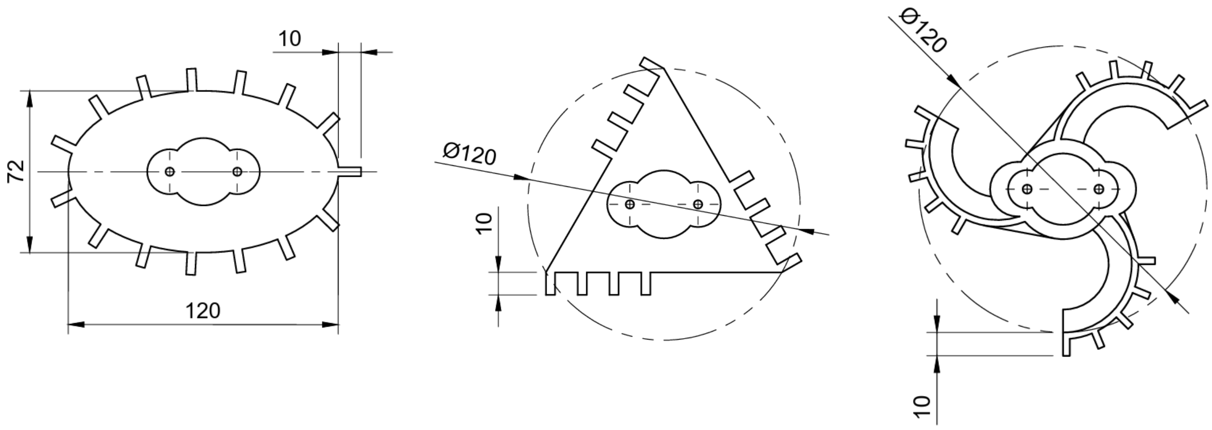
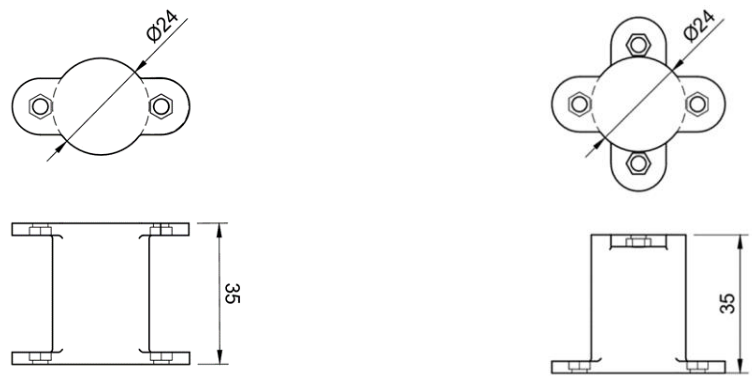


Figure 1 Outline figure of rover body.



(a) Elliptical wheel (b) Triangular wheel (c) 3 bladed wheel

Figure 2 Wheel shape.



(a) Same phase (b) Opposite phase(only Elliptical wheel)

Figure 3 Shaft.

3. Experimental results and discussion

The rovers of all wheels successfully climb slopes from 10° to 30° in same phase and opposite phase running. The running time at an incline of 30° is shorter in opposite phase than in same phase for the elliptical and triangular column wheels. On the other hand, for the three-bladed wheel, the running time in same phase is shorter than in opposite phase. There is no significant difference in power consumption between in same phase and in opposite phase in the case of the elliptical column wheel. In the case of the triangular column wheel, the power consumption of opposite phase reduces more than same phase. In the case of the three-bladed wheel, the power consumption of same phase reduces more than the same phase The amount of slip per wheel revolution obtained from the Image J analysis is shown in Figure 4 and the actual distance travelled minus the slip from the distance travelled forward is shown in Figure 5.

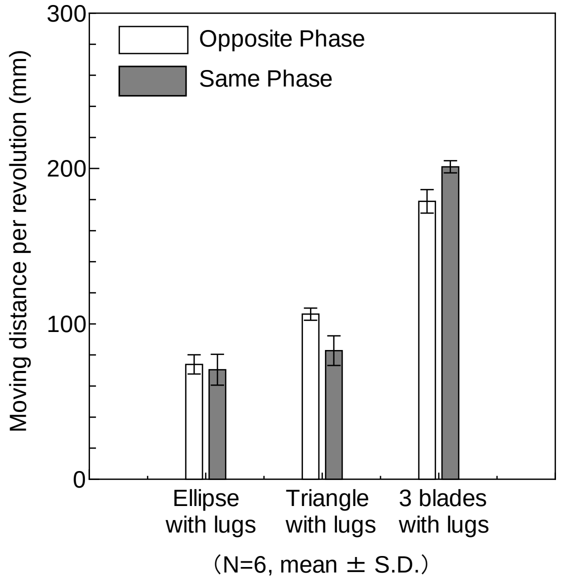


Figure 4. Slip distance per revolution.

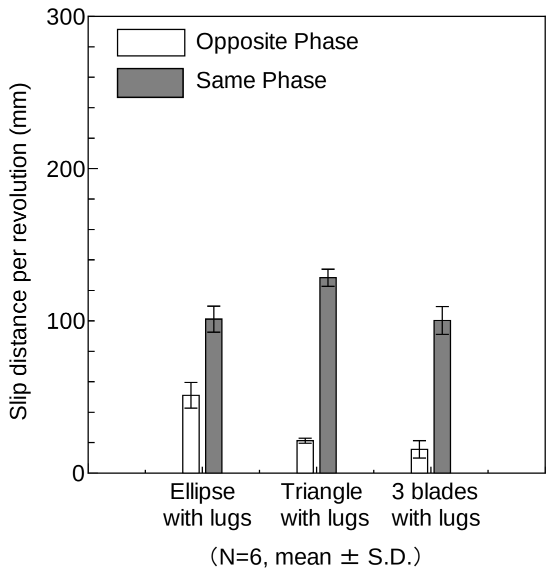
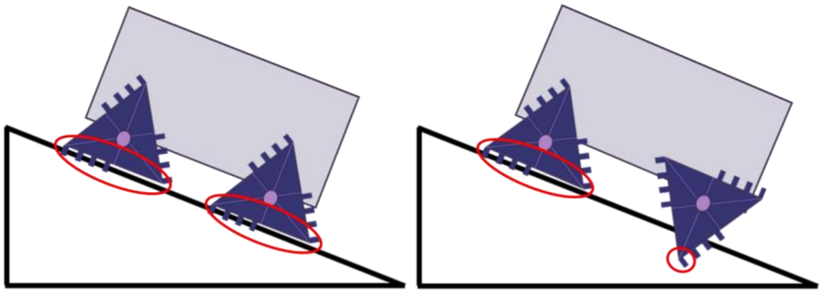
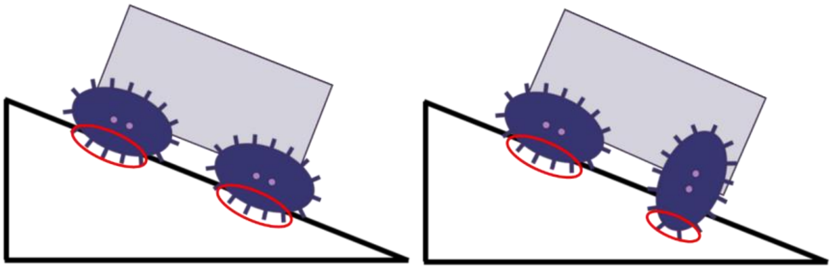


Figure 5 Moving distance per revolution.

The moving distance considering slip is 28 % greater in opposite phase for the triangular column wheel and 11 % greater in same phase for the three-bladed wheel. On the other hand, there is no significant difference in the case of elliptical column wheels. One possible reason for these results could be the contact area between the wheel and the slope: as shown in Figure 5, wheels with a large contact area between the wheel and the slope, such as the triangular pillar wheel, slip occurs when one side of the wheel is aligned with the slope when in same phase. In the opposite phase, when one side of the slope and the front wheel are aligned, the rear wheel is prevented from slipping because the apex of the wheel is in contact with it. The difference between the ground contact area of the front and rear wheels in the same and opposite phase is smaller for elliptical column wheels than for triangular column wheels.



(a) Triangular column wheel



(b) Elliptical column wheel

Figure 5 Differences in grounded area

Furthermore, wheels with a small contact area between the wheel and the slope, such as three-bladed wheels, are more effective in same phase, as slip can be suppressed in same phase.

4. Conclusion

In this study, a four-wheeled small lunar rover was built and its driving performance was evaluated by controlling the wheel phase on a driving test site that reproduced the lunar surface. It was found that the influence of wheel phase control varied depending on the wheel geometry. For wheels with a large contact area between the slope and the wheel, the opposite phase is effective, while the same phase is effective for smaller wheels.

References

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