Design for wheel grouser geometry to direct planetary hopping rover

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ABSTRACT

The rovers have explored the red planet for nearly two decades, providing a wealth of scientific data. However, surface mobility, intelligence, and resistance to harsh environment on planetary bodies remain challenging tasks. Many researchers have been working on constructing an interaction model between planetary terrain and mobility mechanism based on experiments. This paper presents the quasi-optimal design of the wheel grouser geometry based on the theory using the resistive force (RFT). The draw-bar pull with sinkage in a smaller amount is appeared through the numerical calculations and experiments using the single wheel testbed.

1 INTRODUCTION

The rovers have explored the red planet for nearly two decades, providing a wealth of scientific data. However, surface mobility, intelligence, and resistance to harsh environment on planetary bodies remain challenging tasks. Future explorations will especially demand enhanced mobility on more challenging terrains. Over the past half century, many researchers have been working on constructing an interaction model between planetary terrain and machine based on experiments in the research field called Terramechanics [1]. Recently, Li et al. [2] proposed an alternative means to the conventional terramechanics model. Similarly, based on experimental results, Li's method only needs to measure the reaction force (RF) when a small flat plate moves through the particulate matter, and the parameter to be used is also limited to one called scaling factor (SF). For comparative analysis of wheel grousers and landing pads with complex geometry and partially well-known sand characteristics of the planetary surface, the theory using RF (RFT) is considered as a means of linking this analysis to an appropriate mechanical design.

In this study, we consider about the development of a hopping rover which is used in bodies with different gravitational force, such as small bodies and moons. In order to realize the hopping movement as shown in Fig.1, it is necessary to overcome large gravity, instantaneously release the potential energy, and obtain a large reaction force from a soft terrain. The kinetic energy and the reaction force for operation of the hopping rover in the higher gravity planet are unlikely to be compared with the rover on a small body.

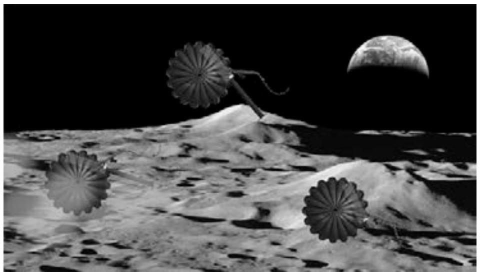

Figure 1: Image of a lunar hopping rover

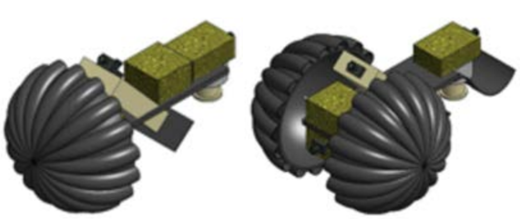

Figure 2: Examples of the hopping rover with a single and double wheels

2 HOPPING ROVER

In such a hopping rover, it is important to jump with high precision in an arbitrary direction, and we consider to employ wheels for directing of hopping. Considering the restriction of a planetary exploration rover, it is appropriate that the number of wheels is 1 or 2, as illustrated in Fig.2, and it is desirable that the number of actuators is also small because of weight reduction. That is, for directing with the single actuator, one wheel is fixed with a clutch or the like in order to perform in-situ rotation in the case of two wheels. Even in the case of single wheel, the function of returning inverse attitude of the hopping rover body to normal attitude is required. For both purposes, the hopping rover requires not only a large draw-bar pull by the wheels but also a large reaction force that it keeps staying there, that is, by a large bulldozing force.

In this study, we design a wheel grouser geometry with the features in order to earn the large draw-bar pull on the regolith with sinkage in a smaller amount and to generate the large reaction force in bulldozing against the regolith. Moreover, for optimization of the geometry regarding to the sinkage, RFT is employed.

3 DESIGN OF GEOMETRY

First, through numerical calculations, when a linear grouser has an inclination within a certain envelope area, the obtained draw-bar pull is calculated and it is found that the largest draw-bar pull is generated at 90 degrees on the inclination, as shown in Fig.3. Further, it is also confirmed that the largest reaction force in bulldozing is generated by the same 90 degrees grouser geometry, as illustrated in Fig.4.

Second, we conducts single wheel running tests and investigates the movement in one direction with the wheel-grouser geometries shown in Fig.5. As the result, it is found that a large draw-bar pull is obtained by the same geometry with sinkage in a smaller amount as compared to the wheel with flat and rectangular grousers, as shown in Fig.6.

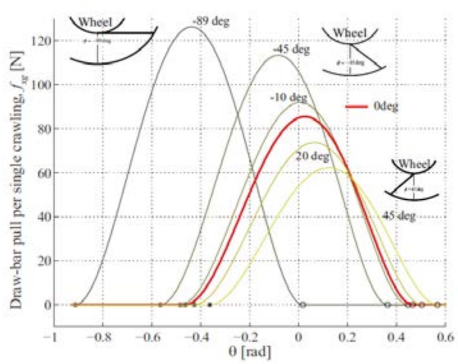

Figure 3: The relation due to tilted angle of the grouser between draw-bar pull and rotational angle of the wheel grouser geometry

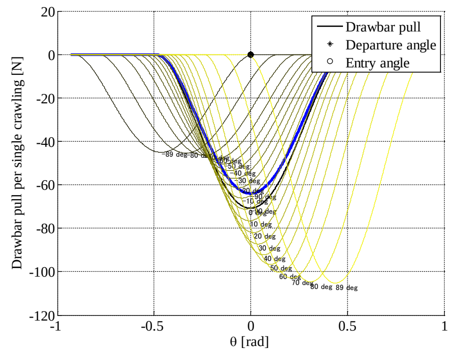

Figure 4: The relation due to tilted angle to the grouser reaction force by bulldozing on the front regolith

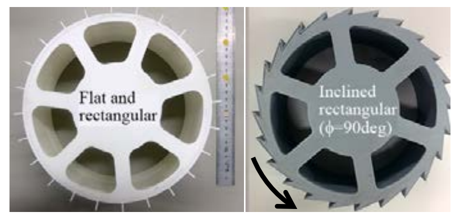

Figure 5: The wheels for the experiments, manufactured by a 3D printer with resin

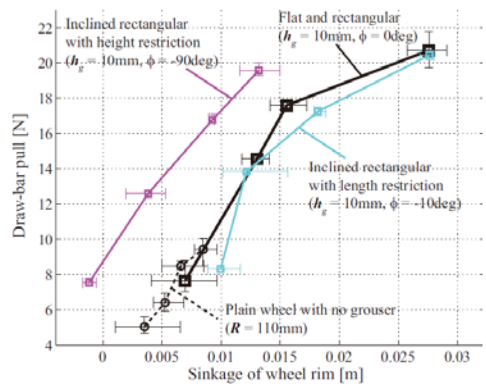

Figure 6: The relations between draw-bar pull and sinkage of the wheel-grouser geometry with the proposed and comparative designs through the experiments

4 CONCLUSION

In conclusion, this study presented the design results of the wheel-grouser geometry which increases the draw-bar pull and the bulldozing force for controlling the direction of the hopping rover with one or two wheels employed on the high gravity planet such as the moon and Mars. Through the numerical calculations and the experiments, it was confirmed that the designed wheel grouser geometry implements large amounts of force with sinkage in a smaller amount.

Acknowledgement

This works was partially supported by JSPS KAKENHI Grant Numbers JP18K04038.

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