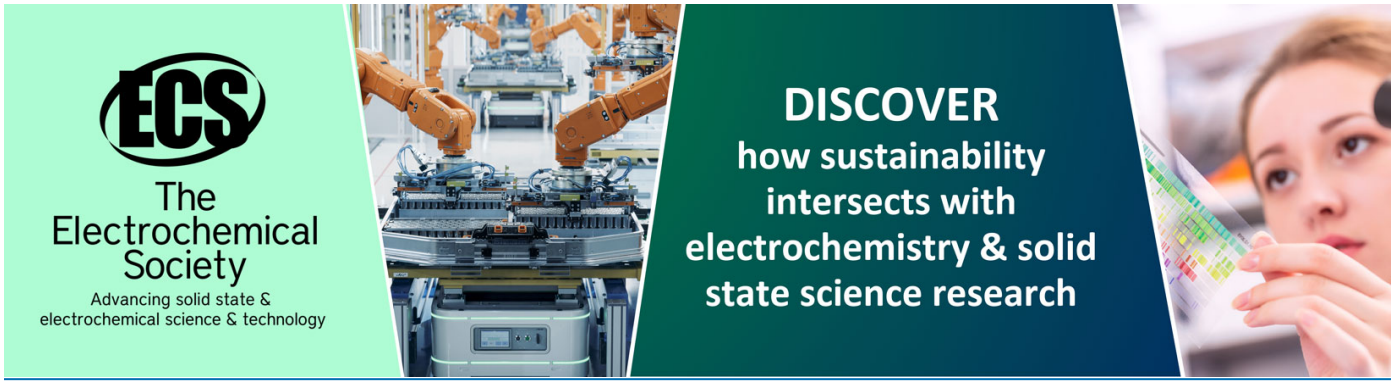
Study on connection between shape of wheel and resistance force from ground for small wheel typed rovers



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Study on connection between shape of wheel and resistance force from ground for small wheel typed rovers

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Abstract. In recent years, the small wheel typed rovers are focused on as an exploring rover. However, running performance of the small wheel typed rovers is not good. It is difficult to compact the ground by wheels because weight of these rovers is small. Therefore, drawbar pull is low. In previous research, the movement method which improves the running performance of these rovers using effects which are given by vibration to the ground was proposed. Some experiments were carried out in order to confirm effective of proposed method. From theses experimental results, we could get knowledge that how to use vibration to improve running performance for the small wheel typed rovers. Moreover, it was confirmed that sinkage of the wheels to the ground is increased when vibration is given to the ground from the wheel. Sinkage of the wheels to the ground decrease running performance of rover. In this research, the relationship between the shape of wheel and resistance force from the ground was confirmed in order to propose the wheel which reduce subsidence amount to the ground when vibration is given to the ground. In experimental results, the wheel which has flange on side reduced subsidence amount to the ground.

1. Introduction

In recent years, the small wheel typed rovers are focused on as an exploring rover[1][2][3]. Volume and weight of these rovers are small. Cost of exploring the moon and Mars can be reduced by using these rovers. However, running performance of the small wheel typed rovers is not good. It is difficult to compact the ground by wheels because weight of these rovers is small. Therefore, drawbar pull of them is low. In previous research, the movement method which improves the running performance of these rovers using effects which are given by vibration to the ground was proposed. When the loose ground is given vibration, there are two effects. One is to increase density and shear strength by compaction of the loose ground. The other is to increase sinkage of wheels because the ground is softened by moving particle of the ground. As a result, the value of shearing strength and sinkage of wheel were increased after vibration. Furthermore, these effects given by vibration are confirmed using the small wheel typed testbed. From theses experimental results, we could get knowledge that how to use vibration to improve running performance for the small wheel typed rovers.

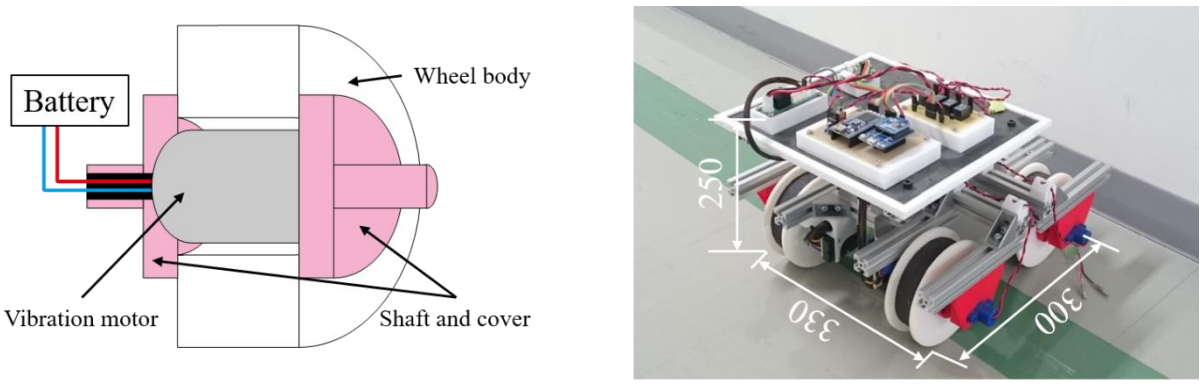
Moreover, it was confirmed that sinkage of the wheels to the ground is increased when vibration is given to the ground from the wheel. Sinkage of the wheels to the ground decrease running performance of the rover. In this research, the relationship between the shape of wheel and resistance force from the ground was confirmed in order to propose the wheel which reduce subsidence amount to the ground when vibration is given to the ground.

2. Running method used vibration

In this chapter, mechanism of running method used vibration which is proposed by our study group is explained. In addition, how to use changes of the ground when giving vibration in proposed running method is explained.

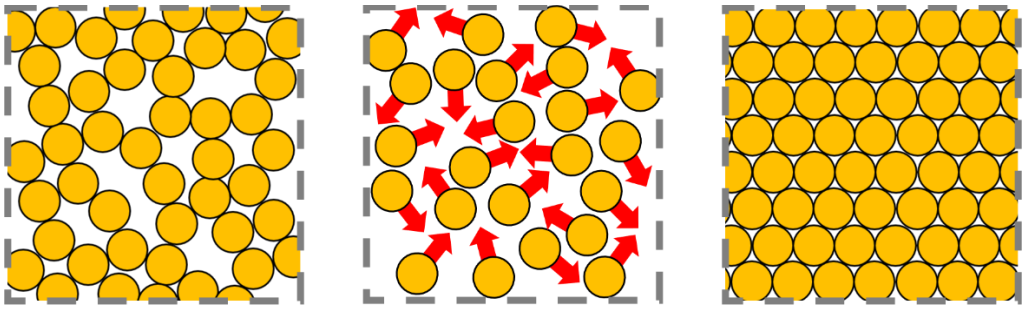
The proposed wheel which gives the ground to vibration is shown in Fig. 1. The vibration motor is attached to internal of wheel. In previous study, the testbed was constructed by four vibration wheels. Moreover, it was confirmed that running performance of the testbed is improved by vibrating the front wheels and running. The ground is compacted by vibrating the front wheels. Therefore, it is considered that the traction force is increased because the rear wheels run on the compacted ground. Actually, it is confirmed that shear strength of the ground is increased by giving the ground to vibration[4]. Particle of the ground is moved by giving the ground to vibration as shown in Fig. 2. Shear strength of the ground is increased by moving particle of the ground.

However, sinkage of the wheels to the ground is also increased by moving particle of the ground. Sinkage of the wheels to the ground decrease running performance of the rover. Therefore, it is needed to develop the solution which reduce subsidence amount to the ground when vibration is given to the ground.



(a) Structure of vibration wheel (b) Overview of testbed

Figure 1. Overview of vibration wheel and testbed.



(a) Before vibration (b) Vibrating (c) After vibration

Figure 2. Movement particles which constitute ground when vibration is given to ground.

3. Penetration experiment for measuring resistance force from ground

Sinkage of the wheels to the ground is increased when resistance force from the ground is small. It is needed to confirm that relationship between the shape of wheel and resistance force from the ground. Therefore, the penetration experiment for measuring resistance force from the ground is conducted. In this chapter, the testing machine, the experimental method and the result of this experiment are reported.

3.1. Penetration testing machine

The penetration testing machine is explained. This machine is consisted of soil tank part, wheel part and actuator part as shown in Fig. 3. Fig. 4 shows movement of this machine. Wheel part is penetrated in soil tank part by actuator part. Wheel part is consisted of force sensor and vibration wheel. The resistance force from the ground when penetrating vibration wheel is measured by force sensor.

3.2. Content of experimental method

Flow of this experiment is explained. First, the ground is mixed and flattened. Wheel part is set on the ground. Next, wheel part is penetrated in soil tank. Speed of moving wheel part is 0.55mm/s. 2 patterns of the experiment are carried out. One is the pattern that wheel part is penetrated while vibrating. Other is the pattern that wheel part is penetrated without vibration. The force sensor receives value of resistance force from the ground. The number of trials is 10 times. Fig. 5 shows flow of this experiment. Table 1 shows condition of this experiment.

In this experiment, 4 kinds of wheel are used. Fig. 6 shows these wheels. As shown in Fig. 6(c), some protrusions which is called rag are attached to the surface of rag typed wheel. The wheel which is similar rag typed wheel were used by some rovers which carried out the space exploration[5][6]. Therefore, it is important to confirm that the relationship between reg typed wheel and resistance force from the ground. Flange typed wheel has flange on side as shown in Fig. 6(d). Study group of Yamakawa developed the wheel which has flange on side and confirmed that this shape is effective to reduce subsidence amount to the ground from experimental result[7]. In this experiment, flange typed wheel is used in order to confirm that this shape is effective to reduce subsidence amount when vibrating or not. Moreover, two flat typed wheel whose diameters are different are used as shown in Fig. 6(a) and Fig. 6(b). Diameters of flat typed wheel(Large) is same as outer diameters of rag typed wheel and flange typed wheel. Diameters of flat typed wheel(Small) is same as inter diameters of rag typed wheel and flange typed wheel. Experimental results of these wheels are compared with other wheels.

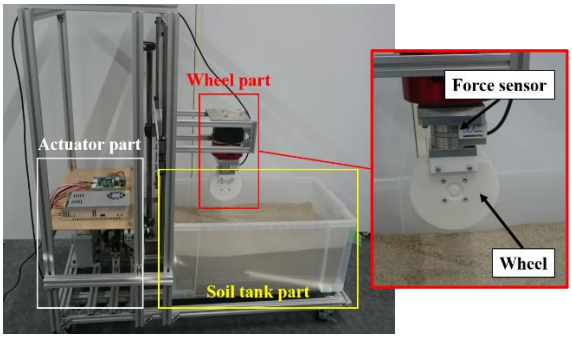


Figure 3. Overview of penetration testing machine.

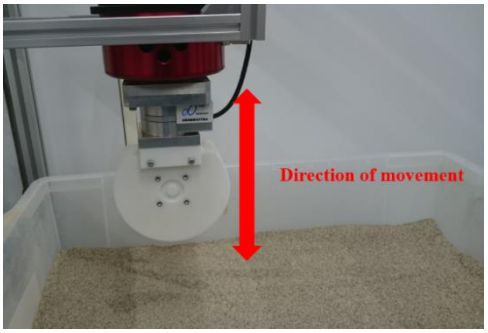
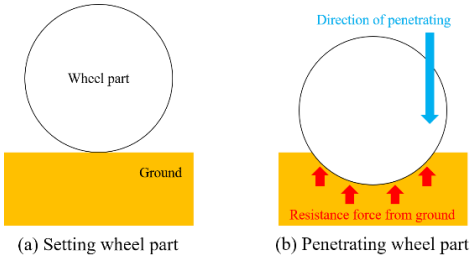


Figure 4. Movement of penetration testing machine.

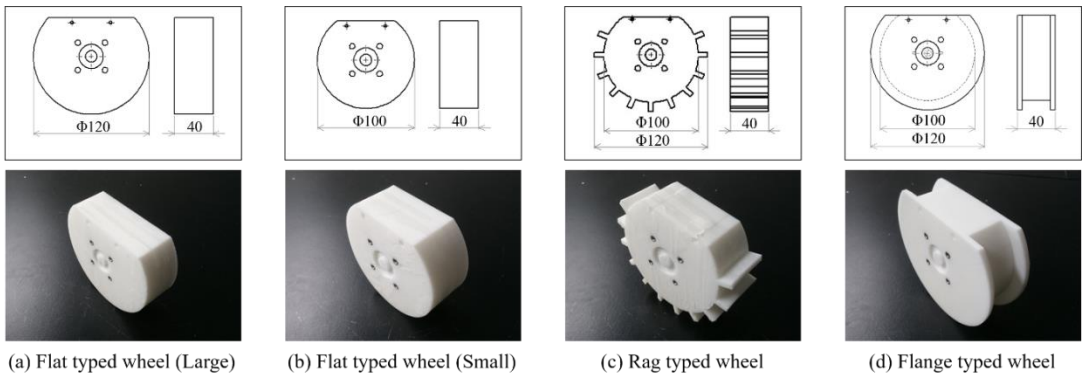


(a) Setting wheel part (b) Penetrating wheel part

Figure 5. Flow of penetration experiment.

Table1. Condition for experiment

Item	Conditions (value)
Number of trial	10 trials
Penetration speed	0.55 mm/s
Pattern	With vibration Without vibration
Kinds of sand	Silica No.5



(a) Flat typed wheel (Large) (b) Flat typed wheel (Small) (c) Rag typed wheel (d) Flange typed wheel

Figure 6. Kinds of wheel.

3.3. Results and Discussion

Fig. 7 to Fig. 10 show the graph about distance of sinkage vs resistance force from the ground each shape of wheel. These graphs show data of median value because these trials in each shape of wheel vary hardly in value. In the case of experiment using flat typed wheel(Large) and rag typed wheel, resistance force from the ground which is measured while vibrating is smaller than that which is measured without vibration. Therefore, these shapes of wheel increase subsidence amount to the ground when these wheels vibrate. On the other hand, resistance force from the ground which is measured while vibrating is not smaller than that which is measured without vibration in the case of experiment using flat typed wheel(Small) and flange typed wheel. Therefore, these shapes of wheel hardly sink to the ground when these wheels vibrate.

Fig. 11 and Fig. 12 are the graph which shows results about same outer diameter of wheels. Fig. 13 shows start line of penetration in each wheel. As the result without vibration, flat typed wheel was most difficult to sink to the ground. Rag typed wheel was second most difficult to sink to the ground. Moreover, flange typed wheel was most easy to sink to the ground. The reason is considered that surface of flat typed wheel which touches the ground is the largest in each wheel. As the result with vibration, rag typed wheel was most easy to sink to the ground. Flat typed wheel was most difficult to sink to the ground in the first half of the graph. However, difference about value of resistance force between flat typed wheel and flange typed wheel is small in the second half of the graph.

Fig. 14 and Fig. 15 are the graph which shows results about same inside diameter of wheels. Fig. 16 shows start line of penetration in each wheel. As the result without vibration, rag typed wheel was most difficult to sink to the ground. Flange typed wheel was second most difficult to sink to the ground. Moreover, Flat typed wheel was most easy to sink to the ground. As the result with vibration, flange typed wheel was most difficult to sink to the ground. Therefore, it is considered that flange typed wheel reduces subsidence amount to the ground when vibrating. The reason is considered that flowing sand is blocked by flange.

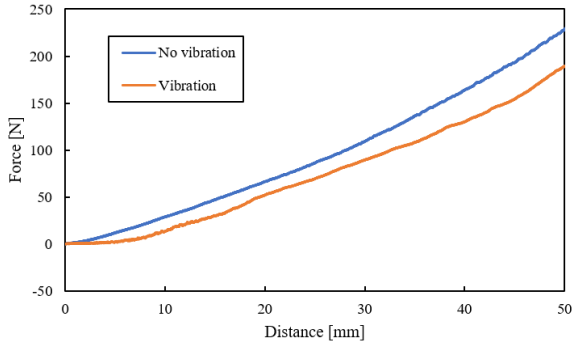


Figure 7. Resistance force vs penetration distance using flat wheel (Large).

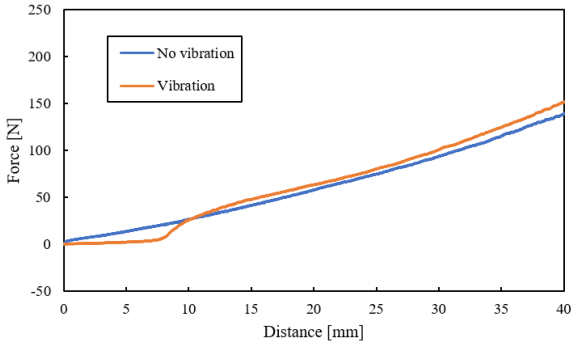


Figure 8. Resistance force vs penetration distance using flat wheel (Small).

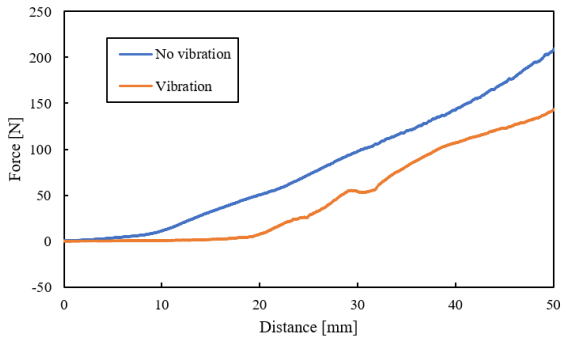


Figure 9. Resistance force vs penetration distance using rag wheel.

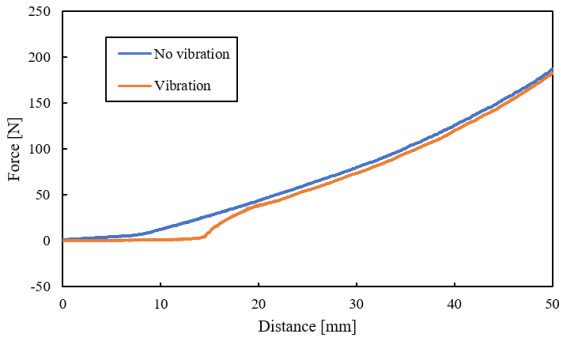


Figure 10. Resistance force vs penetration distance using flange wheel.

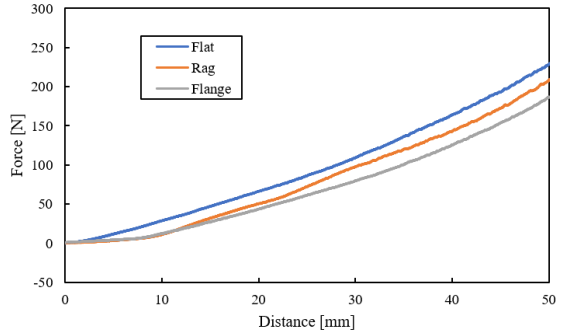


Figure 11. Comparison of resistance force using wheels which are same outer diameter without vibration.

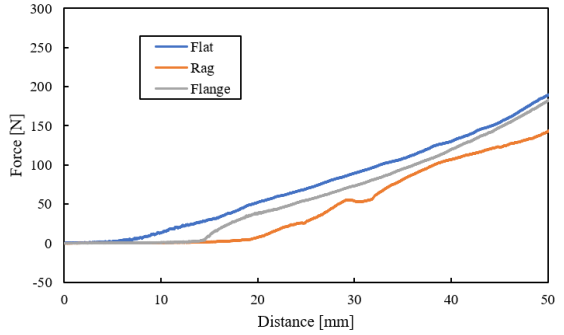


Figure 12. Comparison of resistance force using wheels which are same outer diameter with vibration.

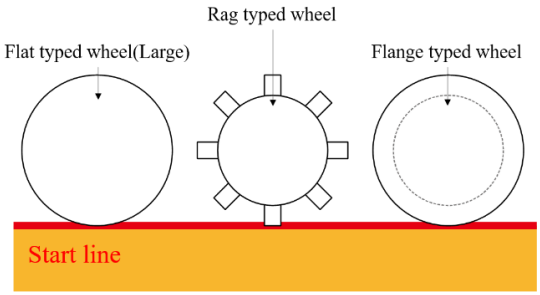


Figure 13. Start line of penetration in each wheel which is same outer diameter.

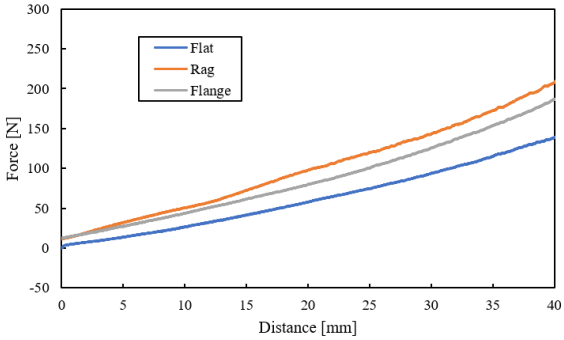


Figure 14. Comparison of resistance force using wheels which are same inside diameter without vibration.

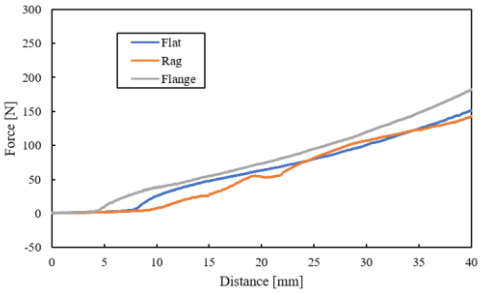


Figure 15. Comparison of resistance force using wheels which are same inside diameter with vibration.

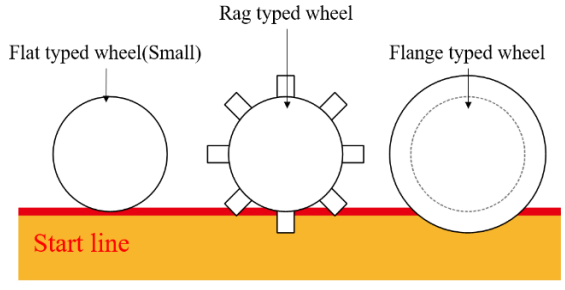


Figure 16. Start line of penetration in each wheel which is same inside diameter.

4. Conclusion

In this study, the relationship between the shape of wheel and resistance force from the ground was confirmed for proposing the wheel which reduce subsidence amount to the ground when vibration is given to the ground. The penetration experiment for measuring resistance force from the ground was conducted. As a result, resistance force from the ground which was measured while vibrating was smaller than that which was measured without vibration in each shape of wheel. The reason is considered that ground becomes soft because sand is flowing by vibration. However, difference of resistance force about flange typed wheel between one with vibration and one without vibration was small. Therefore, the wheel which has flange on side reduced subsidence amount to the ground. The reason is considered that flowing sand is blocked by flange.

From theses experimental results, we could get knowledge about the shape of wheel which reduces subsidence amount to the ground. In the further study, the wheel which reduce subsidence amount to the ground when vibration is given to the ground will be proposed. Moreover, effect of proposed wheel will be confirmed using small wheel typed testbed. In this experiment, the testbed which is attached to proposed wheels will run on the loose ground with slope. Furthermore, movement performance of the testbed will be confirmed.

Acknowledgments

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