Development of test platform for evaluating disturbance characteristics of a lunar soil sampler

Xingwen Gao[1, *], Dewei Tang[1], Deming Zhao[2] and Miao Wu[1]

[1]School of Mechatronics Engineering, Harbin Institute of Technology, Harbin, China
[2]Faculty of Mechanical Engineering & Automation, Zhejiang Sci-Tech University, Hangzhou, China

*Corresponding author e-mail: gaoxing_hit@163.com

Abstract. Lunar soil sampling technique is of great significant scientific and practical significance and hopefully improve the current situation of global energy shortage. Lunar soil sampler is one of the most important parts of drilling and coring system to collect lunar soil sample. The coring method in this paper has the advantages of high recovery rate, low power consumption, effectively keeping the sequence stratigraphy, etc. In this paper, a test platform for evaluating disturbance characteristics of a lunar soil sampler is proposed. The test platform is composition with drilling mechanism, core-pulling mechanism, position servo system of lunar soil simulant container, and rotatable platform, etc. The ground tests of drilling and sampling were carried out to analysis the disturbance state of the sample collected by the lunar soil sampler.

1. Introduction

Recently, lunar exploration has received lots of attention. The results of successful lunar exploration show that the unique resources on the moon is an important supplement of the earth, such as raw materials for nuclear fusion - Helium 3 [1-4] which is regarded as a perfect energy in the 21st century. Solar radiation on the moon is strong, obtaining solar energy will become an important way for people to obtain energy. The special environment of the moon can also provide the conditions for the creation of special process environment and perfect production "raw materials" [5-7]. Chinese lunar exploration project is carried out to achieve the purpose of unmanned automatic sampling and return of the lunar soil samples. The lunar soil sampler on the probe is driven by the drilling and sampling system and collect in-situ lunar soil sample [8].

Whether the lunar soil sampler in lunar soil drilling and sampling system can adapt to the lunar environment, successfully and efficiently collect the sample is a puzzle for us [9]. Test platform for evaluating disturbance characteristics of a lunar soil sampler is used for the functional and performance test of the drilling and sampling system, to verify the mechanical properties, thermal properties and storage performance of the lunar soil sampler in all kinds of typical soil under 1/6 gravity and hot or low temperature environment.

IOP Conf. Series: Earth and Environmental Science **170** (2018) 022104 doi:10.1088/1755-1315/170/2/022104

2. Operating principle of lunar soil sampler

2.1. Overall structure

The drilling and sampling system is composition with drilling mechanism, auger, lunar soil sampler, percussive mechanism and coring bit, as shown in Fig. 1. The lunar soil sampler inside the auger and coring bit is driven downward with the auger and coring bit by the drilling mechanism. When drilling pressure exceeds limit value, the percussive mechanism starts work until the drilling pressure decreases to allowable value. When the drilling and sampling system reaches predetermined depth, the core-pulling mechanism starts work and the sample is stored in sample container.

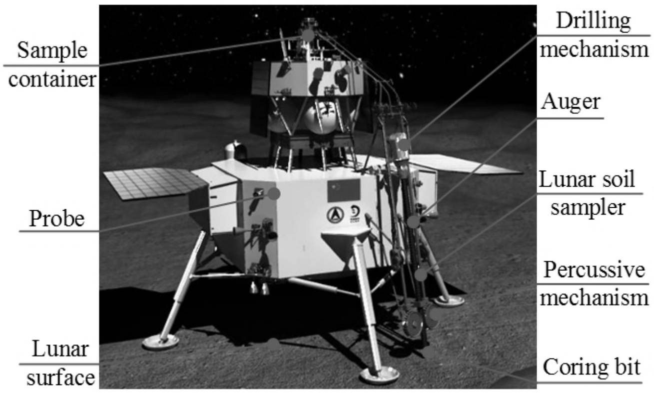

Figure 1. Lunar soil sampler on probe

2.2. Coring method

The lunar soil sampler is composition with rigid tube, flexible tube, floating gripper, and core-retainer, as shown in Fig. 2. In the initial state, the flexible tube sleeve outside the rigid tube. The coring process is divided into three stages: A) the auger and coring bit rotate and are driven downward by the drilling mechanism, the flexible tube turns inside the rigid tube, and the lunar soil particles begin to enter to the flexible tube, B) the drilling and sampling process is ongoing for the duration and the flexible tube continuously turns inside the rigid tube, and core-retainer turns inside the rigid tube, C) when the sealing action finish, the flexible tube is pulled out by the core-pulling mechanism and stored in sample container.

In the process of drilling and sampling, there is no relative motion between the flexible tube and the lunar soil particles, which eliminates the friction between the lunar soil particles and the flexible tube, effectively reduces the core-pulling force and increases the recovery rate of the lunar soil sampler. The sequence stratigraphy of the lunar soil inside the flexible tube almost unchanged compared with the in-situ lunar soil.

IOP Conf. Series: Earth and Environmental Science **170** (2018) 022104 doi:10.1088/1755-1315/170/2/022104

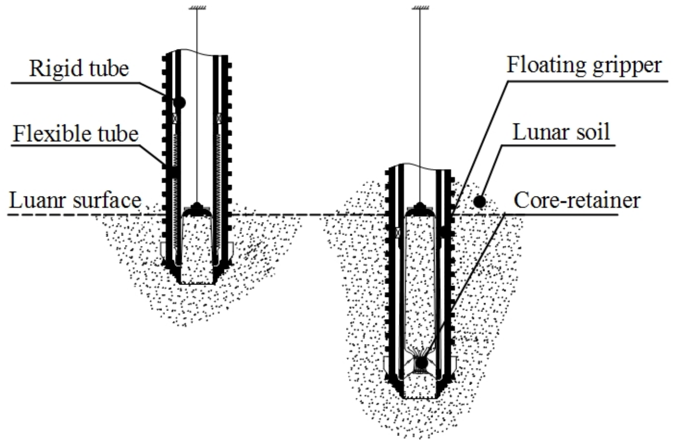

Figure 2. Operating principle of lunar soil sampler

The coring method has the advantages of high recovery rate, low power consumption, effectively keeping the sequence stratigraphy, etc. compared with the direct push sampling method.

3. Development of test platform

Test platform for evaluating disturbance characteristics of a lunar soil sampler is composition with core-pulling mechanism, drilling mechanism, lunar soil simulant container, positioning servo system, sample recovery system, rotatable platform, operating platform, environmental simulation system, data acquisition and control system, and operational software, as shown in Fig. 3.

Rotatable platform: it is used to support the main body of the test platform with adjustable anchor screw and angle adjusting device at the bottom, the stable safety coefficient for supporting >3. Operating platform: the area for operators to install and debug. Positioning servo system: installed on the slide block, the slide block moves on the guide rail to realize the movement of the lunar soil simulant container. Lunar soil sampler: to achieve the purpose of sampling lunar soil simulant. Drilling mechanism: to provide power, the torque of the servo motor is transmitted to the auger and coring bit by the planetary gear reducer and parallel gear reducer and achieve the purpose of rotary-drilling. Core-pulling mechanism: in the process of the drilling and sampling, the rope of the flexible tube presses on the guide wheel of the core-pulling mechanism, under the guide wheel, pressure sensor is installed, so the core-pulling force can be measured. Sample recovery system: the flexible tube filled with the lunar soil sample is wrapped around the winding drum, and the sample is recovered after wrapping. Environmental simulation system: to simulate the low temperature environment of the lunar soil, the hot temperature environment of the drill bit in the drilling process and 1/6 gravity environment of the moon surface. The test platform is shown in Fig. 4.

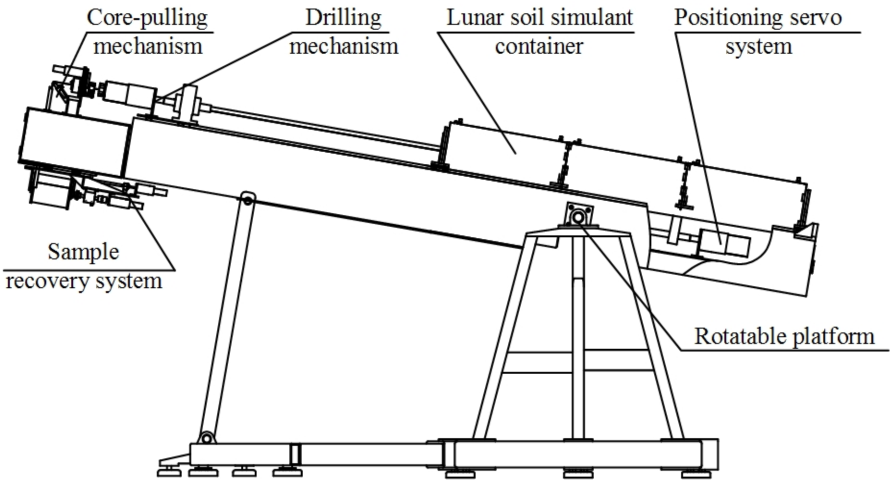

Figure 3. Schematic diagram of test platform

To complete the lunar soil drilling and sampling ground-based test under different environments, rotational motion and feed motion of the drilling mechanism are divided. The feed motion of the drilling and sampling system is converted into the feed motion of the lunar soil simulant container. The lunar soil simulant container feeding mechanism adopts ball screw transmission mechanism and is driven by the positioning servo system. It is known from the load condition analysis that the weight of the lunar soil simulant container which is full of lunar soil simulant is 900 kg, the speed is 0.1 m/min – 2 m/min, and the pressure of bottom container is 600 N. The torque of motor is:

$$P_{\max} = \frac{pl}{2\pi\eta_0} \tag{1}$$

Where P is the output thrust, l the lead, η_0 the screw pair efficiency.

4. Test result

There are three angles between the working position of the test platform for evaluating disturbance characteristics of a lunar soil sampler and the horizontal plane, 9.594°, 70° and 90° respectively. The feed speed of the lunar soil simulant container and the rotating speed of the auger is adjustable, the relative density of lunar soil simulant is also adjustable through the preloading. The sampling depth of standard test is 2.5 m. To verify the functionality of the test platform, the test conditions are shown in Table 1.

Table 1. Test conditions.

Conditions	Value
Angle of position	9.594 °
Temperature	-40 ℃
Sampling depth	2.5 m
Winding drum diameter	200 mm
Relative density	85%
Rotating speed	100 rpm
Feed speed	100 mm/min

First, under the compression of the press, the relative density of the lunar soil simulant is adjusted to 85% and with the method of liquid nitrogen refrigeration, the lunar soil simulant is refrigerated to -40 ℃, then refrigerator stops, and all the refrigerating battery and temperature sensors are removed. Test result is shown in Fig. 5 and Fig. 6.

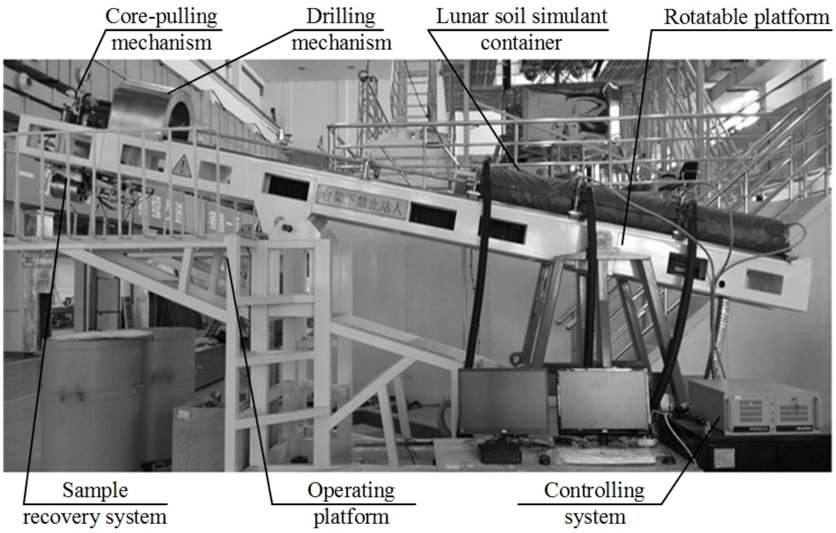

Figure 4. Test platform

According to the test result, in the whole processes of sampling, the force and torque are relatively stable, and increase gradually with the sampling depth. The maximum of the core-pulling force is 50 N, and the maximum of the resistance torque of recovery sample is 6 Nm.

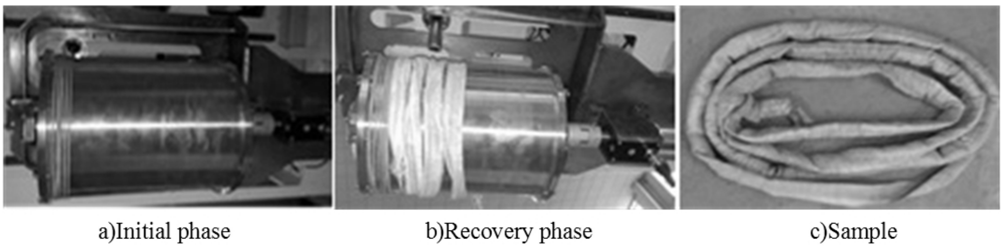

Figure 5. Test result

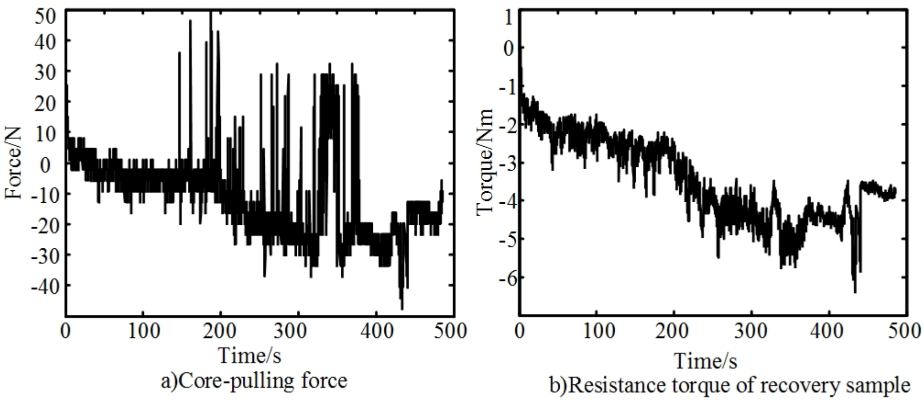

Figure 6. Test result

5. Conclusion

In this paper, the coring method used for the lunar soil sampler is clarified, and the disturbance characteristic parameters of coring method are analyzed. The test platform for evaluating disturbance characteristics of a lunar soil sampler is developed. The test platform is composed of core-pulling mechanism, drilling mechanism, lunar soil simulant container, positioning servo system, sample recovery system, rotatable platform, operating platform, environmental simulation system, data acquisition and control system, and operational software. The coring method has been verified on the test platform. Test results show that this coring method is suitable for lunar soil sampler.

Acknowledgments

This work was financially supported in part by the National Science Foundation of China (Grant No. 51105092), the Pre-research of Chinese Lunar Exploration Program (Grant No. TY3Q20110001 and TY3Q20110005), and the Projects of Technological Transformation of China Academy of Space Technology.

References

[1] Simko T, Gray M. Lunar Helium-3 Fuel for Nuclear Fusion: Technology, Economics, and Resources[J]. World Future Review, 2014, 6(2):158-171.
[2] Ouyang Z Y. Scientific Objectives of Chinese Lunar Exploration Project and Development Strategy[J]. Advance in Earth Sciences, 2004, 19(3):351-358.
[3] Ouyang Z, Zou Y, Chun L I, et al. Prospect of Exploration and Utilization of Some Lunar Resources[J]. Earth Science-journal of China University of Geosciences, 2002, 27(5):498-503.
[4] Chen Z, Feng K. Nuclear Fusion and Feasible Study on Exploitation of Lunar 3He Resource[J]. Science Technology & Engineer, 2004.
[5] Allton J H. Lunar samples: Apollo collection tools, curation handling, SurveyorⅢ and Soviet Luna samples, NASA-JSC-17994[R]. Washington: NASA, 2009.
[6] Berry R L. Launch Window and Translunar, Lunar Orbit, and Transearth Trajectory Planning and Control for the Apollo 11 Lunar Landing Mission[C]. New York: AIAA 8th Aerospace Sciences Meeting, 1970 (1) : 19-21.
[7] Allton J H. Catalog of Apollo Luna Surface Geological Sampling Tools and Con-tainers[R]. USA: Johnson Space Center, NASA, 1989: 5-83.
[8] Zhang J. Research on deep lunar soil corning method design and verification techniques[D]. Harbin Institute of Technology, Harbin, China, 2012
[9] Gao X, Tang D, Yue H, et al. Influence of friction on sampling disturbance of lunar surface in direct push sampling method based on DEM[J]. Advances in Space Research, 2017, 59(12): 3036-3044.