Investigation into the characteristics of granular materials in low gravitational environment (Introduction of Hourglass mission)

*Masatsugu Otsuki[1], Shingo Ozaki[2], Genya Ishigami[3], Takao Maeda[4], Masataku Sutoh[1], Taizo Kobayashi[5], Hideaki Miyamoto[6], Koji Wada[7], Chihiro Kurosawa[1], Yuta Kawai[1], Haruo Kasahara[1], Tetsuya Sakashita[1], Shinobu Doi[1], Hideaki Uchikawa[1], Terumitsu Mano[1]

1. Japan Aerospace Exploration Agency, 2. Yokohama National University, 3. Keio University, 4. Chuo University, 5. Ritsumeikan University, 6. The University of Tokyo, 7. Chiba Institute of Technology

For sample returns from celestial bodies, there is a demand for more advanced technology for safe long stay from the instantaneous touch-and-go method represented by the Hayabusa series spacecrafts. In the future, landing exploration on the moon and Martian moons is also planned in Japan and understanding the interaction with regolith in the low gravitational environment on the surface of the target celestial body is the key to design spacecraft equipments. Thus, it is considered that the experimental data set for obtaining the parameters to identify behavior of the granular materials under low gravity for long time is still highly valuable. To observe the behavior of granular material such as regolith under low gravity, aircraft experiments and drop test have been conducted in the ground test. However, the range for design verification of spacecraft is not only limited due to the time constraints for maintaining the gravitational environment, but the transition from high gravity to low gravity above 1G affects the initial state of the granular material. It has also been recognized that it is a key issue to accurately understand the interaction between particles and mechanical systems in ground tests. Consequently, the "Hourglass" mission has been performed to investigate the gravitational dependence of basic parameters for reproduction of behavior of granular materials such as regolith and ground sand, and to obtain information that contributes to future spacecraft design. This presents the outline of Hourglass mission and its initial results.

In the Hourglass mission, the behaviors of regolith and ground sand in an arbitrary gravity environment are observed with an artificial gravity generator included in the Cell Biology Experiment Facility (CBEF) in the Kibo module of the International Space Station (ISS). The purpose of this mission is to investigate the effect of low gravity on the properties of granular materials. An hourglass-type container and a measuring-cylinder-type container containing particles such as simulated regolith of planets and ground sand are packed into a sealed metal box mounted on the artificial gravity generator. The behavior of particles is observed with an optical camera while they are periodically reversed under arbitrary low gravity. Eight kinds of specimens are employed for the target samples, and dynamic behavior and sedimentation state (bulk density, angle of repose, etc.) of these granular materials are evaluated. Hourglass mission would have the contribution of understanding of the celestial growth process, provision of basic data for the construction of terramechanics on celestial bodies, optimization of design for future landers, exploration rovers, automatic construction machines on the lunar surface and manned pressurized rover for lunar exploration, and the appeal of the value and ability of “Kibo” artificial gravity environment. The initial experimental results revealed the relation between the artificial gravity and the hourglass hour, and the composition of the forces acting on the granular material during experiments using artificial gravity generators.

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