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Sampler, drill and distribution system for cometary soil analysis

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Abstract

This short note describes the activities related to the Sampler, Drill and Distribution subsystem onboard the lander Philae of the Rosetta mission. A dedicated facility has been designed and realized at Politecnico di Milano with a flight spare model of the subsystem to assess its performances in realistic scenarios. The laboratory data are used to identify a relation between the telemetry data and the mechanical characteristics of the cometary soil.

1. Introduction

Rosetta is the third cornerstone mission of the European Space Agency scientific program "Horizon 2000". Rosetta will be the first spacecraft to orbit around a comet nucleus. It was launched in March 2004 and will reach the comet 67P/Churymov-Gerasimenko in 2014. To enhance the scientific capability of the mission, a lander (Philae) will be released and will land on the comet surface for in-situ investigation. Philae will be the first probe to perform a soft landing on a comet nucleus. Its goals include the determination of the elementary and mineralogical composition of the comet, the identification of traces elements, and isotopic composition of cometary material. Comet's surface strength, density, texture, porosity, ice phases and thermal properties will also be investigated.

2. SD2 Description

One of the key subsystems of the lander Philae is the Sampler, Drill and Distribution (SD2) subsystem. SD2 provides in-situ operations devoted to soil drilling, samples collection, and their distribution to two evolved gas analyzers (COSAC and PTOLEMY) and one imaging instrument (ÇIVA). SD2 is mounted on the lander Philae base plate (see Figure 1), and it is equipped with

- a drill able to collect several samples from 10 to 40 mm^3 at different depths. The maximum depth is 230 mm and sample's retrieval is assured by the extraction of a sampling tube from the drill bit;
- a rotating platform (carousel) carrying 26 ovens. The carousel is suitably rotated to release the sample into an assigned oven and to place the filled oven under the proper scientific port;
- an electronic unit, which incorporates all electronics to control the drill and the carousel.

SD2 was designed to work in very low gravity and wide thermal excursion environment, and to optimize cutting performances with a very low power consumption (maximum power request of about 14.5 W).

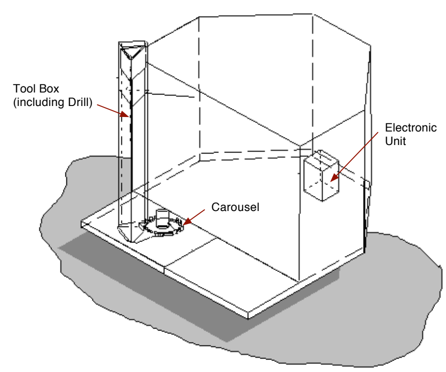

Figure 1: SD2 parts and their distribution on Philae.

3. SD2 Laboratory

The journey of Rosetta to the comet will last about 10 years. During this transfer time, the status of SD2 must be regularly checked during the passive and active payload checkouts. This involves developing dedicated procedures, which must be tested on ground before being uploaded and executed onboard. In addition, SD2 behavior needs to be tested in the many different scenarios that can be encountered on the comet.

A dedicated facility has been designed and realized in the laboratories of Politecnico di Milano to address the previous tasks. More specifically, the SD2 flight spare (FS) model has been secured to a support structure that replicates the clamping system on the flight model (see Figure 2). Two sensors are added to the system: a biaxial strain gauge that measures the normal force and the torque during perforation, and a current sensor to measure SD2 FS power consumption during all drilling phases.

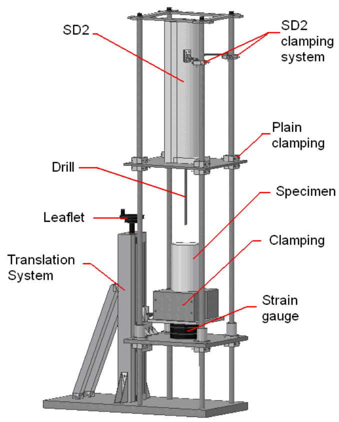

Figure 2: SD2 facility at Politecnico di Milano.

Three kinds of specimens are currently studied, which are meant to simulate the actual cometary soil using different materials: gasbeton, whose specimens are produced with different inclination of the perforated surface to simulate different shapes of the cometary soil; graphitic phoam, which is filled with water and then frozen to assess SD2 performances on icy soils; multilayer, where a first granular gravel layer is followed by a gasbeton layer to study SD2 behavior in soils with varying granularity levels.

4. The Scientific Use of SD2

Recent studies have proven the existence of a correlation between the drill behavior during perforation and the mechanical characteristics of the cometary soil. This outlines the possibility of using SD2 not only as a tool to support other instruments, but also as a scientific instrument itself. To this purpose, a correlation between SD2 telemetry data and the cometary soil characteristics must be identified.

Unfortunately, as the drill rotation and translation are commanded by stepper motors, the variation of power consumption can not be used as an indicator of a variation of the soil characteristics. Consequently, an alternative strategy has been developed, which is based on the identification of the drill working zones in the space of the drill rotation and translation speeds. More specifically, for each specimen, several perforations with decreasing speed levels are performed. For each specimen, specific minimum speed values exist below which the perforation stops, either because the resistance torque is greater than the applied torque or because the maximum Euler buckling load has been reached. Thus, for each specimen and for each commanded torque level, a working zone is identified. Figure 3 illustrates the results for a gasbeton specimen.

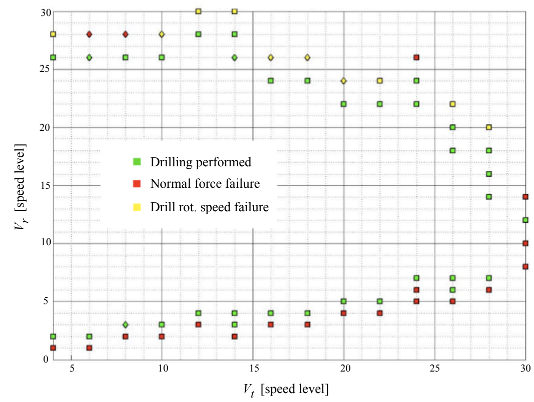

Figure 3: Gasbeton working zone; 0° surface inclination, torque levels 4 and 2 for the drill translation and rotation motors.

The same perforation strategy will be followed on the comet by the SD2 flight model to obtain the working zone specific to the cometary soil. Information about the mechanical characteristics and inhomogeneity of the soil will then be deduced from a comparison between the soil working zone and the specimens working zones obtained on ground.

5. Summary and Conclusions

This note described the instrument SD2 and showed a first attempt to identify a correlation between the drill behavior and the cometary soil characteristics. The first results encourage the scientific use of SD2 as a backup solution to failures of other scientific instruments, due to the power and time consuming perforation strategy necessary to define the drill working zone specific to the cometary soil.

Acknowledgements

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