Surface Mechanical Properties of Comet 67P

W. Arnold[1, a], H.-H. Fischer[2], M. Knapmeyer[3], and H. Krüger[4],
[1]Saarland University, Department of Materials Science and Engineering, Saarbrücken, Germany
and I. Phys. Institut, Georg-August-Universität, Göttingen, Germany
[2]DLR MUSC, Cologne, Germany
[3]DLR Institute of Planetary Research, Berlin, Germany
[4]Max Planck Institute for Solar System Research, Göttingen, Germany

In August 2014 the ESA spacecraft Rosetta encountered the comet 67P/Churyumov-Gerasimenko. The overall objective of the Rosetta mission was to determine physical and chemical properties of comet 67P. The orbiter of Rosetta was itself an instrument platform. It also carried the lander Philae that landed on the comet's nucleus on November 12th 2014. Philae had ten different instruments on board including the Surface Electric Sounding and Acoustic Monitoring Experiment (SESAME) comprising the Comet Acoustic Surface Sounding Experiment (CASSE), the Dust Impact Monitor (DIM), and the electric impedance probe (PP). The mission ended on September 30th 2016 with the deorbiting of Rosetta onto comet 67P.

The Comet Acoustic Surface Sounding Experiment (CASSE) was housed in the soles of Philae's landing-gear feet, see Fig. 1a. The acceleration signals at the first landing site Agilkia which occurred in the first seconds of the touchdown at an impact velocity of approx. 1 m/s were recorded by CASSE (Fig. 1b) [1]. The inversion of the data based on the transfer function of the landing gear and the foot soles yielded the compression strength and the elastic modulus of the cometary soil. Both the compression strength and the elastic modulus of the surface of comet 67P are very low compared to commonly used engineering materials [2]. The data support the concept that the elastic (E) and strength properties (σ) of the comet material correspond to very porous solids constituted by the regolith particles with porosities up to 80%. The σ/E ratio ≈ 1/1000 agrees well with relations known in material science [3]. The data also allow an estimate of the fracture toughness K_{1c} which is compared with data for crack growth observed in the neck of the comet [4]. Furthermore, Short-term Fourier-Transforms of the signals give additional hints how the lander comet contact evolved in time.

The Multi-purpose Sensors for Surface and Sub-Surface Science (MUPUS) listening experiment in joint operation with CASSE. The main goal of MUPUS was to measure the thermal properties of the surface comet material[5] . To this end an instrumented rod was hammered into the ground.

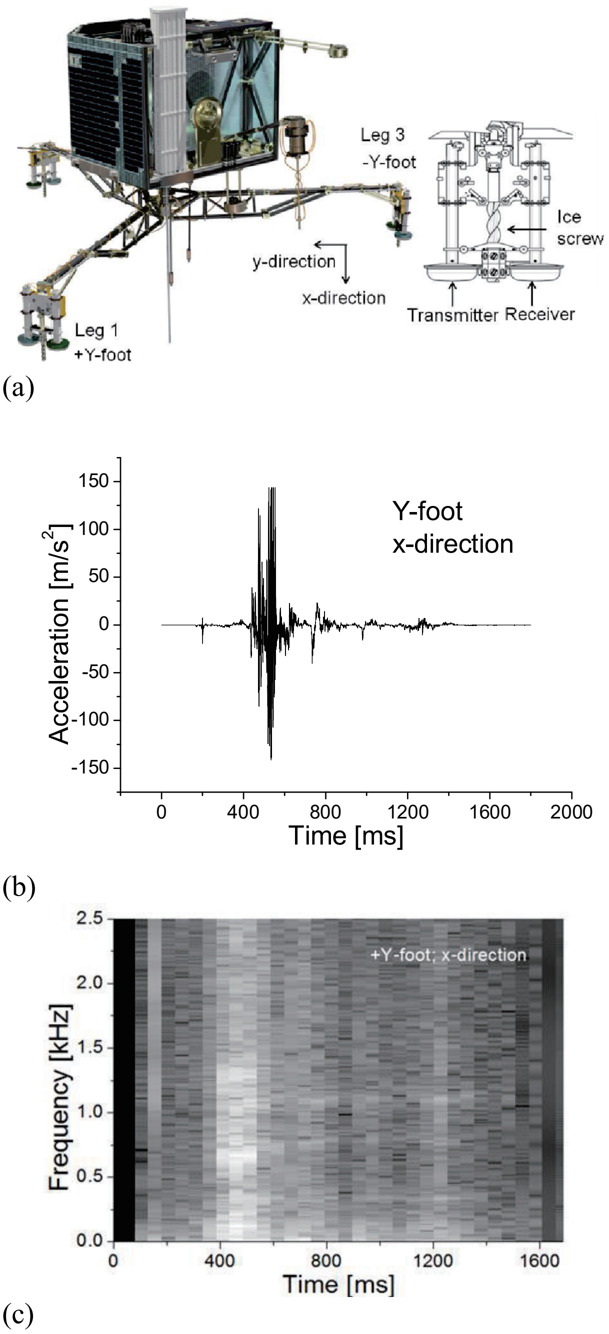

Fig. 1: (a) Lander Philae with three legs, each about 1.5 m long; (b) Touch-down signal (x-direction) of the +Y-foot at Leg 1; (c) Its Short-Term Fourier Transform calibrated in dB relative to the maximal amplitude.

[a] E-mail: w.arnold@mx.uni-saarland.de

MUPUS used the hammering mechanism with stroke energies up to 4 Joules to generate surface waves in the 100 Hz to 2 kHz range at the final landing site Abydos. Group arrival time differences between the three feet of Philae were measured and the Rayleigh wave velocity was derived. From the signals dispersion, one can conclude that comet 67P at Abydos is structurally layered [6].

The Dust Impact Monitor (DIM) on board of Philae consisted of a cube with PZT detectors. DIM was aimed to derive the elastic-plastic properties and the flux of the millimeter-sized dust-particle population that moves near the surface of the comet nucleus. During the descent phase of Philae, a signal was recorded of a dust particle by the DIM detector and its diameter and elastic modulus was derived [7]. A detailed analysis of the small signal strength and its long duration implied a porous particle whose properties lied close to aerogel particles having a porosity of ≈ 90%. Because their Young's modulus was ≈ 10 MPa, it was conjectured that the particle detected possessed a similar value [8].

In this presentation, an overview on the course of the Rosetta mission is given and data recorded by CASSE and DIM are presented. The SESAME measurement techniques used on comet 67P are compared to those used in non-destructive materials characterization using ultrasonic measurement techniques to measure the thickness of thin films by SAW dispersion [9], and to exploit contact-resonances in dynamic atomic force microscopy [10,11], and in mechanical impedance testing [12,13].

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