SPACE EXPLORATION SYMPOSIUM (A3)
Mars Exploration – Part 2 (3B)

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IDENTIFICATION OF THE FORCES BETWEEN REGOLITH AND A RECIPROCATING DRILL-HEAD: PERSPECTIVES FOR THE EXPLORATION OF MARTIAN REGOLITH

Abstract

The large success of Mars exploration missions, such as the NASA Mars Exploration Rovers, Pathfinder and Viking I and II, have allowed a widespread access to the top layer of Martian regolith. However, no exploration deeper than the few centimetres allowed by the scoop of Phoenix has been conducted on Mars. The potential discoveries that will follow from access to the Martian sub-surface (for example, the presence or absence of extinct life forms and of resources for future human exploration; a better understanding of Martian and Solar System history) require the development of new tools and a better understanding of their interaction with regolith to increase their performance and reliability.

A promising new drilling methodology, dual reciprocating drilling (DRD), was tested in regolith and showed higher penetration than static penetration. DRD is conducted by two half-cone drill-heads, with back-ward facing teeth, moved back and forth in opposition one to another (no rotation). To gain a better understanding of the forces acting on each half-drill-bit and the influence of slippage on drilling performance, a mono-block drill-head, with the same shape as the DRD drill-head, was tested in static and alternating penetration in two different regolith simulants. The forces acting on it were measured. It was observed that in very loose regoliths (low relative density), the reciprocation motion compacts the regolith around the drill head and leads to higher penetration forces. However in very highly compacted regoliths, the reciprocation motion locally lowers the force required to penetrate to a given depth.

To complement the experimental campaign and to gain a better insight on the regolith kinematics around the reciprocating drill-head, numerical simulations were developed. The discrete element method was chosen to simulate the complex behaviour of regolith. It was implemented within the commercial software Impetus-Afea. The advantage of using this platform is its ability to use the power of graphical processing units (GPU) to cope with a very large number of elements within reasonable computation times.

The practical implications of these novel experimental and numerical results for Martian regolith exploration will be discussed. Amongst others, these results have lead to the revision of the dual-reciprocating-drill prototype design and have also allowed the identification of methods for increasing penetration depths of static penetrators without significant hardware modifications (through reciprocation). Finally the advantage of GPU-based numerical simulations for hardware/regolith interaction

simulation and space-hardware design will also be illustrated.