PENETRATION TESTING FOR SUBSURFACE REGOLITH PROBES IN MARTIAN ANALOG MATERIAL

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ABSTRACT

Subsurface planetary investigation is currently of highly interest to the scientific community. Delivering a probe or instrument would enhance subsurface analysis.The Optical Probe for Regolith Analysis (OPRA) is a subsurface analytical probe that is going to investigate the subsurface of planetary bodies. The spike-like shaped probe will be delivered to a planet, asteroid, or cometary body by a lander and/or rover. OPRA will be pushed down into the subsurface to record near infrared spectra as a function of depth down to a maximum of 50 cm. The main objective of this research is to determine the most optimized parameters which facilitate the insertion and withdrawal of OPRA from the subsurface. In this research, we are determining the effect of bulk density (B.D) and diameter (D) to insert a probe in martian analog materials such as JSC Mars-1 (palagonite) and Mojave Mars Simulant (unaltered basaltic sand) (MMS), a basaltic sand. An automated control apparatus was designed and built to measure the insertion and withdrawal forces of the OPRA probe in unconsolidated materials. A list of probes was used to simulate the OPRA probe in the penetration tests ranging in diameter from (1.9, 1.2, 0.9 and 0.5 cm). Increasing probe diameter from 0.5 cm to 1.2 cm leads to an increase in penetration force from 200 N to 1100 N in MMS and from 300 N to 1000 N in JSC Mars-1 at 30 cm depth. An increase in bulk density from 1180 kg/m^3 to 1440 kg/m^3 leads to an increase in penetration force 30 N to 450 N in MMS and from 895 kg/m^3 to 1061 kg/m^3 cause an increase in penetration force 20 N to 500 N in JSC Mars-1 at 30 cm depth. Bearing capacity theory can be used to explain the downward movement of the penetrometer through regolith [1], [2]. We applied its theoretical model to sand due to the knowledge of the bearing capacity factor Nq where it showed a good agreement with the experimental results [3]. We then applied it to predict the force due to penetration on other planetary bodies such as Mars and the moon where we are taking the effect of gravity into our considerations. The predicted force of penetration was in agreement with Apollo 14 penetration lunar data at 42 to 50 cm and at 62 cm depth while the model was higher than the results of Apollo 15 and 16 by 145 N at 76 cm depth. We applied the model to predict the required energy of penetration on Mars. In compacted JSC Mars-1 (B.D = 1090 kg/m^3) with 1 cm square probe indicate a requirement of 170 J to achieve about 0.4 m. Based on our results and theoretical model, compaction is the most dominant effect on the penetration force, the diameter of the probes being the second. The peak rate of required power for probe insertion in JSC Mars-1 using a 1cm square probe will be only about 3 W.

References: [1] Terzaghi, K. Theoretical soil mechanics, 1943. [2] Vesic, B. A. Bearing capacity of deep foundations in sand, 1963. [3] Puech, A., and P. Foray. Refined model for interpreting shallow penetration CPTs in sands, Offshore Technology Conference, 6 -9 May 2002, Houston, Texas, 2002.