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Small high-speed penetrator as a source and a receiver of seismic waves

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Abstract

Seismic waves are used for studying planets and other celestial bodies. Seismic location can give information about structure of layers close to surface and deep layers of celestial bodies, size of their kernels and much more. Small high-speed penetrators (SHSP), interacting with space body at velocities 1.5….2.5 km/s, are a source of seismic waves, which develop during the penetration. On the other hand SHSP can carry various scientific instrumentation onboard, first of all, seismometers, as well as instrumentation for measuring thermal, some electrical, magnetic and electromagnetic phenomena. The most important problems during penetrator design process are ensuring that accelerations do not exceed allowed values, and possibility to control its trajectory during penetration into celestial bodies.

1. Ways of reducing acceleration

Acceleration can be reduced with help of cavitator at the end of front section of penetrating module, ensuring formation of a cavitation crater and reducing contact zone between module and lunar soil [1]. For interaction velocities about two kilometers per second cavitator can be made as a solid rod with length compared to the length of penetrating module. At such interaction velocities application of cavitators from stowed flexible element with length significantly exceeding length of penetrating module is possible. Such cavitator stretches out from stowed state before impact with a celestial body.
It is possible to use two types of cavitators:
- undeformable (Fig. 1, a) from very hard material (metalloceramics, carbonfibers); in this case initial length of cavitator is preserved during penetration and it can have initial length of about 0.1...1.0 m;
- deformable or eroding (Fig. 1, b) metal or from composite materials; in this case decreasing of penetrator length takes place during penetration, and its initial length can be from several tenths of centimeters up to several meters depending on material used.

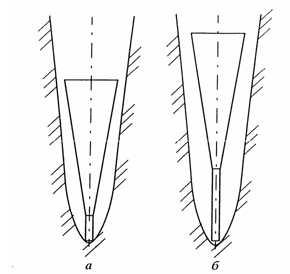

Figure 1: Cavitator types (a) - undeformable, (b) - deformable.

Another means of reducing acceleration experienced by penetrator's instrument compartment is including a gas damper in penetrator body [2]. Gas damper can be made as a chamber filled with pressurized gas in front of instrumental compartment (Fig. 2). It allows to reduce maximal acceleration during the initial stage of penetration.

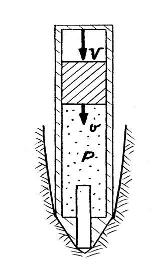

Figure 2: Reducing acceleration using gas damper.

2. Ways of controlling penetrator trajectory

While investigating celestial bodies with penetrators, and Moon in particular, a curvature of their trajectory might be required in order to turn it towards daylight surface and prevent its interaction with hard inner layers which can result in penetrator breakage.

Effect of reducing penetration depth can in this case be reached by adding stabilizer which would have asymmetric position with respect to penetrator's axis of symmetry in the beginning of penetration. Because of interaction with formed cavity walls penetrator would experience torque turning it towards daylight surface. Such of penetrator can also ensure penetrator motion in regolith parallel to the surface.

Another option of reducing penetration depth would be creating curvature of the trajectory in the direction of daylight surface by creating a cut on front part of the cavitator.

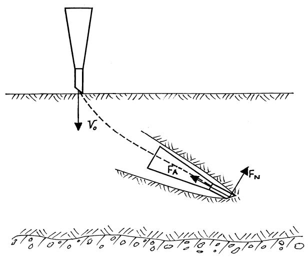

Figure 3: Penetration process with a skew-cut cavitator.

Cut angle is a function of maximal acceptable axial and lateral accelerations, and also of friction coefficient between regolith and penetrator material, and is in the range between 45°…90°. Lateral to axial acceleration ratio is:

$$\frac{F_N}{F_A} = \frac{1 - \mu \tan \lambda}{\mu + \tan \lambda} \qquad (1)$$

where λ - cut angle measured from axis of the penetrator, μ - friction coefficient between resisting medium and surface of the penetrator (Fig.3).

3. Summary and Conclusions

Penetrator as a research instrument is crucial for many problems of experimental cosmogony, and different compartments of this device have already successfully passed many tests; it is economically affordable, and its realization in the scope of present technologies can be fulfilled without principal difficulties.

Acknowledgements

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References

[1] V.Veldanov, V.Smirnov, O.Khavroshkin. High-speed penetrator for research of an internal structure of the moon. The 3-rd international conference on the exploration and utilization of the moon. Abstracts, october 11-14, 1998, Moscow, Russia, p. 57.

[2] V.A. Veldanov, A.N. Naumov. The spatial motion of penetrator with overload damper of an instrument module. 18th International Symposium & Exhibition on Ballistics. November 15-19, 1999, San Antonio, Texas, US