Ultrasonic/sonic drilling/coring (USDC) for planetary applications

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Future NASA exploration missions are increasingly seeking to conduct sampling, in-situ analysis and possibly return material to Earth for further tests. Missions to Mars are the more near term projects that are seeking such capabilities. One of the major limitations of sampling on Mars and other low gravity environments is the need for high axial force when using conventional drilling. To address this limitation an ultrasonic/sonic drilling/coring (USDC) mechanism has been developed that employs an ultrasonic horn driven by a piezoelectric stack. The horn drives a free mass that resonates between the horn and drill stem. Tests have shown that the USDC addresses some of the key challenges to the NASA sampling objectives. The USDC is lightweight (450 g), requires low preload (< 5N) and can be driven at low power (5W). The device has been shown to drill rocks with various levels of hardness including granite, diorite, basalt and limestone. The hammering action involved with the coring process can produce cores of various shapes, which need not necessarily be round. This capability makes the USDC an effective tool for delivery of in-situ instruments down the well, production of miniature building blocks, as well as ability to dig tunnels, storage areas and fulfill other infrastructure needs of future human habitation on Mars or other planets. Because it is driven by piezoelectric ceramics, USDC is highly tolerant to changes in its operating environment. These actuation materials can be designed to operate at a wide range of temperatures including those expected on Mars and Venus. As a result of the transverse and longitudinal motions involved with this drilling mechanism, the coring bit creates a hole that is slightly larger than the drill bit diameter. This reduces the chances of bit jamming if the integrity of the hole is maintained, thus avoiding one of the problem associated with conventional drilling. The ultrasonic bit need not be sharp and various drill bits can be designed to take advantage of this novel enabling technology. Although the drill is driven electrically at 20 kHz a substantial sub-harmonic acoustic component is found that is crucial to drilling performance. An analytical model has been developed to explain this low frequency coupling in the horn, free mass, drill stem and rock.