Method for Cleanly and Precisely Breaking Off a Rock Core Using a Radial Compressive Force

This technique can be used by civil engineers in rock, ground, and concrete coring and sampling.

NASA's Jet Propulsion Laboratory, Pasadena, California

The Mars Sample Return mission has the goal to drill, break off, and retain rock core samples. After some results gained from rock core mechanics testing, the realization that scoring teeth would cleanly break off the core after only a few millimeters of penetration, and noting that rocks are weak in tension, the idea was developed to use symmetric wedging teeth in compression to weaken and then break the core at the contact plane. This concept was developed as a response to the break-off and retention requirements.

The wedges wrap around the estimated average diameter of the core to get as many contact locations as possible, and are then pushed inward, radially, through the core towards one another. This starts a crack and begins to apply opposing forces inside the core to propagate the crack across the plane of contact.

The advantage is in the simplicity. Only two teeth are needed to break five varieties of Mars-like rock cores with limited penetration and reasonable forces. Its major advantage is that it does not require any length of rock to be attached to the parent in order to break the core at the desired location. Test data shows that some rocks break off on their own into segments or break off into discs. This idea would grab and retain a disc, push some discs upward and others out, or grab a segment, break it at the contact plane, and retain the portion inside of the device. It also does this with few moving parts in a simple, space-efficient design.

This discovery could be implemented into a coring drill bit to precisely break off and retain any size rock core.

This work was done by Megan Richardson and Justin Lin of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-47444

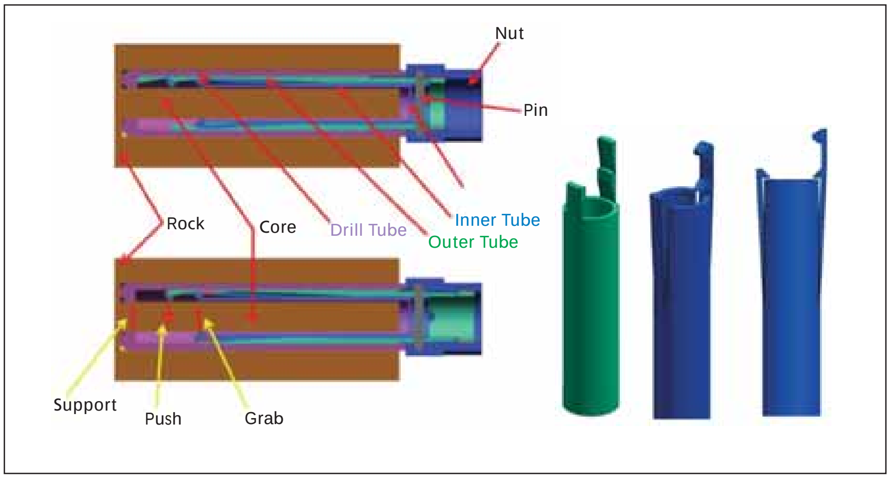
Praying Mantis Bending Core Breakoff and Retention Mechanism

This mechanism has application in sampling cores for analytical tests of geological materials.

NASA's Jet Propulsion Laboratory, Pasadena, California

Sampling cores requires the controlled breakoff of the core at a known location with respect to the drill end. An additional problem is designing a mechanism that can be implemented at a small scale, yet is robust and versatile enough to be used for a variety of core samples.

The new design consists of a set of tubes (a drill tube, an outer tube, and an inner tube) and means of sliding the inner and outer tubes axially relative to each other. Additionally, a sample tube can be housed inside the inner tube for storing the sample. The inner tube fits inside the outer tube, which fits inside the drill tube. The inner and outer tubes can move axially relative to each other. The inner tube presents two lamellae with two opposing grabbing teeth and one pushing tooth. The pushing tooth is offset axially from the grabbing teeth. The teeth can move radially and their motion is controlled by the outer tube. The outer tube presents two lamellae with radial extrusions to control the inner tube lamellae motion. In breaking the core, the mechanism creates two support points (the grabbing teeth and the bit tip) and one push point. The core is broken in bending. The grabbing teeth can also act as a core retention mechanism.



The **Praying Mantis Core Breakoff Mechanism** design assembly (left), and (right) the outer (green) and inner tubes (blue).

The praying mantis that is disclosed herein is an active core breaking/retention mechanism that requires only one additional actuator other than the drilling actuator. It can break cores that are attached to the borehole bottom as well as broken cores, and it also acts as a core retention device. The cores are broken at the bottom of the sample tube with a clean cut. The invention uses a core bending principle and does not induce additional axial load on the drill/robotic arm.

This invention is potentially applicable to sample return and *in situ* missions to planets such as Mars and Venus, moons such as Titan and Europa, and comets. It is also applicable to terrestrial applications like forensic sampling and geological sampling in the field.

This work was done by Mircea Badescu, Stewart Sherrit, Yoseph Bar-Cohen, Xiaoqi Bao, and Randel A. Lindemann of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-47356

Scoring Dawg Core Breakoff and Retention Mechanism

NASA's Jet Propulsion Laboratory, Pasadena, California

This novel core break-off and retention mechanism consists of a scoring dawg controlled by a set of two tubes (a drill tube and an inner tube). The drill tube and the inner tube have longitudinal concentric holes. The solution can be implemented in an eccentric tube configuration as well where the tubes have eccentric longitudinal holes. The inner tube presents at the bottom two control surfaces for controlling the orientation of the scoring dawg. The drill tube presents a sunk-in profile on the inside of the wall for housing the scoring dawg. The inner tube rotation relative to the drill tube actively controls the orientation of the scoring dawg and hence its penetration and retrieval from the core. The scoring dawg presents a shaft, two axially spaced arms, and a tooth. The two arms slide on the control surfaces of the inner tube. The tooth, when rotated, can penetrate or be extracted from the core.

During drilling, the two tubes move together maintaining the scoring dawg completely outside the core. After the desired drilling depth has been reached the inner tube is rotated relative to the drill tube such that the tooth of the scoring dawg moves toward the central axis. By rotating the drill tube, the scoring dawg can score the core and so reduce its cross sectional area. The scoring dawg can also act as a stress concentrator for breaking the core in torsion or tension. After breaking the core, the scoring dawg can act as a core retention mechanism.

For scoring, it requires the core to be attached to the rock. If the core is broken, the dawg can be used as a retention mechanism. The scoring dawg requires a hard-tip insert like tungsten carbide for scoring hard rocks. The relative rotation of the two tubes can be controlled manually or by an additional actuator. In the implemented design solution the bit rotation for scoring was in the same direction as the drilling. The device was tested for limestone cores and basalt cores. The torque required for breaking the 10-mm diameter limestone cores was 5 to 5.8 lb-in. (0.56 to 0.66 N-m).

This work was done by Mircea Badescu, Stewart Sherrit, Yoseph Bar-Cohen, Xiaoqi Bao, and Paul G. Backes of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-47355

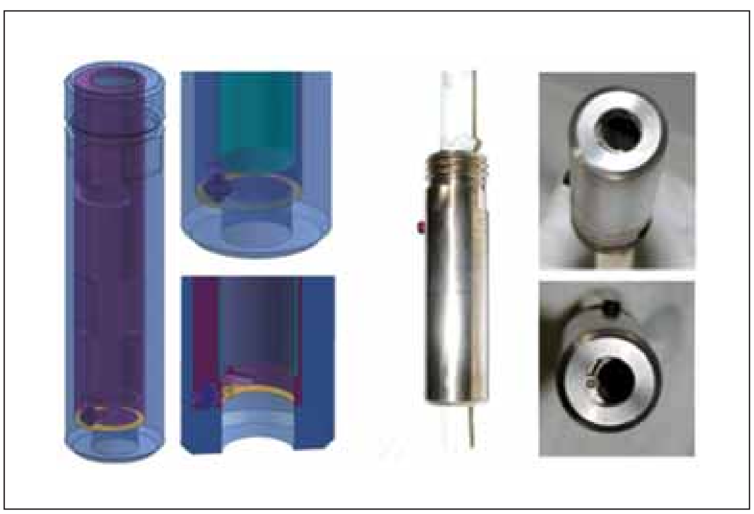
Rolling-Tooth Core Breakoff and Retention Mechanism

The mechanism has applications in analytical tests of geological materials.

NASA's Jet Propulsion Laboratory, Pasadena, California

Sampling cores requires the controlled breakoff of the core at a known location with respect to the drill end. An additional problem is designing a mechanism that can be implemented at a small scale that is robust and versatile enough to be used for a variety of core samples. This design consists of a set of tubes (a drill tube and an inner tube) and a rolling element (rolling tooth). An additional tube can be used as a sample tube. The drill tube and the inner tube have longitudinal holes with the axes offset from the axis of each tube. The two eccentricities are equal. The inner tube fits inside the drill tube, and the sample tube fits inside the inner tube.

While drilling, the two tubes are positioned relative to each other such that the sample tube is aligned with the drill tube axis and core. The drill tube includes teeth and flutes for cuttings removal. The inner tube includes, at the base, the rolling element implemented as a wheel on a shaft in an eccentric slot. An additional slot in the inner tube and a pin in the drill tube limit



The **Rolling-Tooth Design** of the core breakoff and retention mechanism (left), and the assembled parts (right).