# Mechanics/Machinery

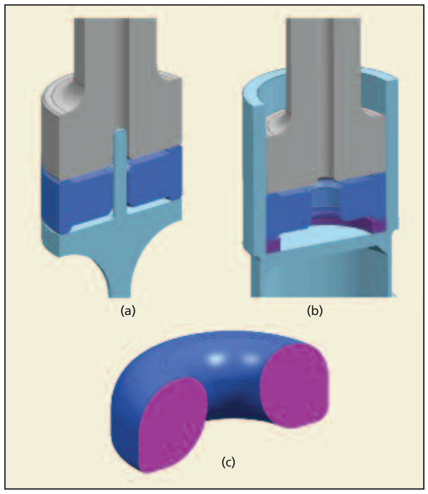
## Free-Mass and Interface Configurations of Hammering Mechanisms

### These mechanisms are applicable for construction or other industries requiring drills or actuators.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A series of free-mass designs for the ultrasonic/sonic driller/corer (USDC) has been developed to maximize the transfer of energy from the piezoelectric transducer through the horn to the bit, as well as to minimize potential jamming. A systematic development was made producing novel designs of free-mass configurations where the impact force is spread across a minimal area maximizing the impact on the bit. The designed free masses were made to operate at high temperatures (500 °C) as on Venus, and they can be made to operate at extremely low temperature, too.

In normal operation, the free mass bounces between the horn and the bit, impacting both repeatedly. The impact stress profile, maximum stress, contact time duration, and the required yielding stress for the materials of the free mass, bit, and horn are all affected by the contact area. A larger contact area results in lower stress in the contact region, and avoids yielding of the materials. However, before the excitation voltage is applied to the transducer, the horn, free mass, and the bit are pressed together. Larger contact area results in a stronger coupling of the bit to the horn transducer, which greatly changes the vibration characteristics of the transducer, and makes the USDC difficult to start.




In the improved **USDC Design**, the rod was eliminated, and a solid cylinder-shaped free mass retained with a "cup" was used. On the left (a) is shown the rod configuration for the retention of the free mass, and on the right (b) the cup configuration is shown for the free mass retention. Part (c) shows a free mass with flat and curved contact areas.

To obtain optimum performance, a catalog of free-mass designs is required, allowing maximum flexibility during trade-off for these conflicting contact area requirements.

For this purpose, seven different designs were conceived: point contacts, circular contacts, point/circular contacts, line contacts, ring contacts, line/ring contacts, and dashed line contacts. Besides point/circular and line/ring contacts, the free mass can be designed as any of the above shapes. Depending on the ratio of the diameter to the height, and the free-mass retention method used (the cup or rod), the free mass can be configured with one or more sliding surfaces on the outside or inside diameter surface or both. Matching horn tips and free mass may also offer some utility in maximizing the stress pulse.

*This work was done by Xiaoqi Bao, Stewart Sherrit, Mircea Badescu, Yoseph Bar-Cohen, Steve Atkins, and Patrick N. Ostlund of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

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*Refer to NPO-47780, volume and number of this* NASA Tech Briefs *issue, and the page number.*

## Wavefront Compensation Segmented Mirror Sensing and Control

### Six degrees of freedom can be sensed at each segment edge.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

The primary mirror of very large submillimeter-wave telescopes will necessarily be segmented into many separate mirror panels. These panels must be continuously co-phased to keep the telescope wavefront error less than a small fraction of a wavelength, to ten microns RMS (root mean square) or less. This performance must be maintained continuously across the full aperture of the telescope, in all pointing conditions, and in a variable thermal environment.

A wavefront compensation segmented mirror sensing and control system, consisting of optical edge sensors, Wavefront Compensation Estimator/Controller Software, and segment position actuators is proposed. Optical edge sensors are placed two per each segment-to-segment edge to continuously measure changes in segment state. Segment position actuators (three per segment) are used to move the panels. A computer control system uses the edge sensor measurements to estimate the state of all of the segments and to predict the wavefront error; segment actuator commands are computed that minimize the wavefront error.

Translational or rotational motions of one segment relative to the other cause lateral displacement of the light beam, which is measured by the imaging sensor. For high accuracy, the collimator uses a shaped mask, such as one or more slits, so that the light beam forms a pattern on the sensor that permits sensing accuracy of better than 0.1 micron in two axes: in the z or local surface normal direction, and in the y direction parallel to the mirror surface and perpendicular to the beam direction.

Using a coaligned pair of sensors, with the location of the detector and collimated light source interchanged, four degrees of freedom can be sensed: transverse x and y displacements, as well as two bending angles (pitch and yaw). In this approach, each optical edge sensor head has a collimator and an imager, placing one sensor head on each side of a segment gap, with two parallel light beams crossing the gap.

Two sets of optical edge sensors are used per segment-to-segment edge, separated by a finite distance along the segment edge, for four optical heads, each with an imager and a collimator. By orienting the beam direction of one edge sensor pair to be +45º away from the segment edge direction, and the other sensor pair to be –45º away from the segment edge direction, all six degrees of freedom of relative motion between the segments can be measured with some redundancy.

The software resides in a computer that receives each of the optical edge sensor signals, as well as telescope pointing commands. It feeds back the edge sensor signals to keep the primary mirror figure within specification. It uses a feed-forward control to compensate for global effects such as decollimation of the primary and secondary mirrors due to gravity sag as the telescope pointing changes to track science objects.

Three segment position actuators will be provided per segment to enable controlled motions in the piston, tip, and tilt degrees of freedom. These actuators are driven by the software, providing the optical changes needed to keep the telescope phased.

A novel aspect of this design is the angled optical edge sensor configuration. By angling the light beam of each edge sensor pair at + and –45º, a full four degrees of freedom can be sensed at each segment edge by each sensor pair. This configuration results in full observability of the segment optical state, and is crucial in achieving the needed performance.

The software incorporates a structural/optical model of the telescope in a least-squares or Kalman filter-based estimator/controller, which processes the optical edge sensor signals in a low-bandwidth control loop. The estimator produces an estimate of the optical state of the mirror, and predicts the resulting wavefront error, balancing current against previous measurements in a least-squares optimization. The controller calculates the segment actuator commands that will minimize not the sensor signals, but the predicted wavefront error. This formulation allows the controller to compensate for the optical effects of motions (such as lateral sag of the segments) that are not directly actuated. The result is far better performance than could be achieved using a conventional sensor-nulling approach.

*This work was done by David C. Redding, John Z. Lou, Andrew Kissil, Charles M. Bradford, David Woody, and Stephen Padin of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

*The software used in this innovation is available for commercial licensing. Please contact Daniel Broderick of the California Institute of Technology at danielb@caltech.edu. Refer to NPO-47964.*

# Long-Life, Lightweight, Multi-Roller Traction Drives for Planetary Vehicle Surface Exploration

**These drives can be used for Earth-based applications where extreme temperatures are involved.**

*John H. Glenn Research Center, Cleveland, Ohio*

NASA's initiative for Lunar and Martian exploration will require long lived, robust drive systems for manned vehicles that must operate in hostile environments. The operation of these mechanical drives will pose a problem because of the existing extreme operating conditions. Some of these extreme conditions include operating at a very high or very cold temperature, operating over a wide range of temperatures, operating in very dusty environments, operating in a very high radiation environment, and operating in possibly corrosive environments.

Current drive systems use gears with various configurations of "teeth." These gears must be lubricated with oil (or grease) and must have some sort of a lubricant resupply system. For drive systems, oil poses problems such as evaporation, becoming too viscous and eventually freezing at cold temperatures, being too thin to lubricate at high temperatures, being degraded by the radiation environment, being contaminated by the regolith (soil), and if vaporized (and not sealed), it will contaminate the regolith. Thus, it may not be advisable or even possible to use oil because of these limitations.

An oil-less, compact traction vehicle drive is a drive designed for use in hostile environments like those that will be encountered on planetary surfaces. Initially, traction roller tests in vacuum were conducted to obtain traction and endurance data needed for designing the drives. From that data, a traction drive was designed that would fit into a prototype lunar rover vehicle, and this design data was used to construct several traction drives. These drives were then tested in air to determine their performance characteristics, and if any final corrections to the designs were necessary.

A limitation with current speed reducer systems such as planetary gears and harmonic drives is the high-contact stresses that occur at tooth engagement and in the harmonic drive wave generator interface. These high stresses induce high wear of solid lubricant coatings, thus necessitating the use of liquid lubricants for long life.

Because of their near-pure rolling contact, traction drives can operate unlubricated at very cold temperatures or