



Mechanics/Machinery

⚙️ Planar Rotary Piezoelectric Motor Using Ultrasonic Horns

These motors are scalable and can be used in small systems such as motors in electronic cameras or small flight instruments.

NASA's Jet Propulsion Laboratory, Pasadena, California

A motor involves a simple design that can be embedded into a plate structure by incorporating ultrasonic horn actuators into the plate. The piezoelectric material that is integrated into the horns is pre-stressed with flexures. Piezoelectric actuators are attractive for their ability to generate precision high strokes, torques, and forces while operating under relatively harsh conditions (temperatures at single-digit K to as high as 1,273 K).

Electromagnetic motors (EM) typically have high rotational speed and low torque. In order to produce a useful torque, these motors are geared down to reduce the speed and increase the torque. This gearing adds mass and reduces the efficiency of the EM. Piezoelectric motors can be designed with high torques and lower speeds directly without the need for gears.

Designs were developed for producing rotary motion based on the Barth concept of an ultrasonic horn driving a rotor. This idea was extended to a linear motor design by having the horns drive a slider. The unique feature of these motors is that they can be designed in a monolithic planar struc-

ture. The design is a unidirectional motor, which is driven by eight horn actuators, that rotates in the clockwise direction. There are two sets of flexures. The flexures around the piezoelectric material are pre-stress flexures and they pre-load the piezoelectric disks to maintain their being operated under compression when electric field is applied. The other set of flexures is a mounting flexure that attaches to the horn at the nodal point and can be designed to generate a normal force between the horn tip and the rotor so that to first order it operates independently and compensates for the wear between the horn and the rotor.

This motor could be stacked to increase the torque on the rotor, or flipped and stacked to produce bidirectional rotation. The novel features of this motor are:

- A monolithic planar piezoelectric motor driven by high-power ultrasonic horns that can be manufactured from a single piece of metal using EDM (electric discharge machining), precision machining, or rapid prototyping.
- A plate structure that can rotate a rotor in a plane.

- A flexure system with low stiffness that accommodates mechanical wear at the rotor horn interface and maintains a constant normal force.
- The ability to embed many horns in a plate to increase the torque.
- A rotary actuator that can be designed to rotate clockwise or counterclockwise, depending on the direction of extension of the horn with respect to the center axis of the rotor.
- A linear actuation mechanism that operates bidirectionally in the plate.
- A mechanism that is operated with soft flexure springs that maintains constant normal and hence friction forces in a motor.
- A planar rotary piezoelectric motor that is driven by ultrasonic horns that can be stacked to produce higher torques.
- Actuator plates that can be flipped and stacked to produce bidirectional drive.

This work was done by Stewart Sherrit, Xiaoqi Bao, Mircea Badescu, and Yoseph Bar-Cohen of Caltech; Daniel Geiyer of Rochester Institute of Technology; and Patrick N. Ostlund and Phillip Allen of Cal Poly Pomona for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-47813

⚙️ Self-Rupturing Hermetic Valve

NASA's Jet Propulsion Laboratory, Pasadena, California

For commercial, military, and aerospace applications, low-cost, small, reliable, and lightweight gas and liquid hermetically sealed valves with post initiation on/off capability are highly desirable for pressurized systems. Applications include remote fire suppression, single-use system-pressurization systems, spacecraft propellant systems, and *in situ* instruments. Current pyrotechnic-activated rupture disk hermetic valves were designed for physically larger systems and are heavy and integrate poorly with portable equipment, aircraft, and small spacecraft and

instrument systems. Additionally, current pyrotechnically activated systems impart high g-force shock loads to surrounding components and structures, which increase the risk of damage and can require additional mitigation.

The disclosed mechanism addresses the need for producing a hermetically sealed micro-isolation valve for low and high pressure for commercial, aerospace, and spacecraft applications. High-precision electrical discharge machining (EDM) parts allow for the machining of mated parts with gaps less than a thousandth of an inch. These

high-precision parts are used to support against pressure and extrusion, a thin hermetically welded diaphragm. This diaphragm ruptures from a pressure differential when the support is removed and/or when the plunger is forced against the diaphragm. With the addition of conventional seals to the plunger and a two-way actuator, a derivative of this design would allow non-hermetic use as an on/off or metering valve after the initial rupturing of the hermetic sealing disk. In addition, in a single-use hermetically sealed isolation valve, the valve can be activated without

the use of potential leak-inducing valve body penetrations.

One implementation of this technology is a high-pressure, high-flow-rate rupture valve that is self-rupturing, which is advantageous for high-pressure applications such as gas isolation valves. Once initiated, this technology is self-energizing and requires low force compared to current pyrotechnic-based burst disk hermetic valves.

This is a novel design for producing a single-use, self-rupturing, hermetically sealed valve for isolation of pressurized gas and/or liquids. This design can also be applied for single-use disposable valves for chemical instruments. A welded foil diaphragm is fully supported by two mated surfaces that are machined to micron accuracies using EDM. To open the valve, one of the surfaces is moved relative to the other to

(a) remove the support creating an unsupported diaphragm that ruptures due to over pressure, and/or (b) produce tension in the diaphragm and rupture it.

This work was done by Curtis E. Tucker Jr. and Stewart Sherrit of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-47497

Explosive Bolt Dual-Initiated From One Side

Lyndon B. Johnson Space Center, Houston, Texas

An explosive bolt has been developed that has a one-sided dual initiation train all the way down to the pyro charge for high reliability, while still allowing the other side of the bolt to remain in place after actuation to act as a thermal seal in

an extremely high-temperature environment. This lightweight separation device separates at a single fracture plane, and has as much redundancy/reliability as possible. The initiation train comes into the explosive bolt from one side.

This work was done by Eric Snow of Lockheed Martin for Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809. MSC-24843-1

Two-Stage Winch for Kites and Tethered Balloons or Blimps

Goddard Space Flight Center, Greenbelt, Maryland

A winch system provides a method for launch and recovery capabilities for kites and tethered blimps or balloons. Low power consumption is a key objective, as well as low weight for portability. This is accomplished by decoupling the tether-line storage and winding/unwinding functions, and providing tailored and efficient mechanisms for each. The components of this system include rotational power input devices

such as electric motors or other apparatus, line winding/unwinding reel(s), line storage reel(s), and independent drive trains.

Power is applied to the wind/unwind reels to transport the tether line. Power is also applied to a line storage reel, from either the wind/unwind power source, the wind/unwind reel itself, or separate power source. The speeds of the two reels are synchronized, but not

dependent on each other. This is accomplished via clutch mechanisms, variable transmissions, or independent motor controls. The speed of the storage reel is modulated as the effective diameter of the reel changes with line accumulation.

This work was done by Ted Miles and Geoff Bland of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16014-1

Dampers for Stationary Labyrinth Seals

Spring and/or shot dampers are incorporated as integral parts of seals.

Marshall Space Flight Center, Alabama

Vibration dampers have been invented that are incorporated as components within the stationary labyrinth seal assembly. These dampers are intended to supplement other vibration-suppressing features of labyrinth seals in order to reduce the incidence of high-cycle-fatigue failures, which have been known to occur in the severe vibratory environments of jet engines and turbopumps in which labyrinth seals are typically used. A vibration damper of this type includes

several leaf springs and/or a number of metallic particles (shot) all held in an annular seal cavity by a retaining ring. The leaf springs are made of a spring steel alloy chosen, in conjunction with design parameters, to maintain sufficient preload to ensure effectiveness of damping at desired operating temperatures. The cavity is vented via a small radial gap between the retaining ring and seal housing. The damping mechanism is complex. In the case of leaf springs,

the mechanism is mainly friction in the slippage between the seal housing and individual dampers. In the case of a damper that contains shot, the damping mechanism includes contributions from friction between individual particles, friction between particles and cavity walls, and dissipation of kinetic energy of impact.

The basic concept of particle/shot vibration dampers has been published previously; what is new here is the use of