



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, Xiaoyi 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

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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