

Supplying electric power to the solenoids would cause the magnetostrictive cylinders to push radially inward against a set of wedges that would be in axial contact with the stepped disk. The wedges would convert the radial magnetostrictive strain to a multiplied

axial displacement of the stepped disk. This axial displacement would be just large enough to lift the stepped disk, against the permanent magnetic force, out of contact with the ring. The ring would then be free to turn because it would no longer be

squeezed axially between the stepped disk and the hub.

*This work was done by Myron A. Diftler and Aaron Hulse of Lockheed Martin Corp. for Johnson Space Center. Further information is contained in a TSP (see page 1), MSC-23629-1*

## Low-Friction, Low-Profile, High-Moment Two-Axis Joint

**This device can be utilized in robotics, automobile steering, transmission systems, and aircraft control surface linkages.**

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The two-axis joint is a mechanical device that provides two-degrees-of-freedom motion between connected components. A compact, moment-resistant, two-axis joint is used to connect an electromechanical actuator to its driven structural members. Due to the requirements of the overall mechanism, the joint has a low profile to fit within the allowable space, low friction, and high moment-reacting capability. The mechanical arrangement of this joint can withstand high moments when loads are applied. These features allow the joint to be used in tight spaces where a high load capability is required, as well as in applications where penetrating the mounting surface is not an option or where surface mounting is required.

The joint consists of one base, one clevis, one cap, two needle bearings, and a circular shim. The base of the joint is the housing (the base and the cap together), and is connected to the grounding structure via fasteners and a bolt pattern. Captive within the housing, between the base and the cap, are the rotating clevis and the needle bearings.

The clevis is attached to the mechanical system (linear actuator) via a pin. This pin, and the rotational movement of the clevis with respect to the housing, provides two rotational degrees of freedom.

The larger diameter flange of the clevis is sandwiched between a pair of needle bearings, one on each side of the flange. During the assembly of the two-axis joint, the circular shims are used to adjust the amount of preload that is applied to the needle bearings. The above arrangement enables the joint to handle high moments with minimal friction.

To achieve the high-moment capability within a low-profile joint, the use of "depth of engagement" (like that of a conventional rotating shaft) to react moment is replaced with planar engagement parallel to the mounting surface. The needle bearings with the clevis flange provide the surface area to react the clevis loads/moments into the joint housing while providing minimal friction during rotation. The diameter of the flange and the bearings can be increased to react higher loads and still maintain a compact surface mounting capability.

This type of joint can be used in a wide variety of mechanisms and mechanical systems. It is especially effective where precise, smooth, continuous motion is required. For example, the joint can be used at the end of a linear actuator that is required to extend and rotate simultaneously. The current design application is for use in a spacecraft docking-system capture mechanism. Other applications might include industrial robotic or assembly line apparatuses, positioning systems, or in the motion-based simulator industry that employs complex, multi-axis manipulators for various types of motions.

*This work was done by James L. Lewis of Johnson Space Center and Thang Le and Monty B. Carroll of Lockheed Martin. Further information is contained in a TSP (see page 1).*

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center, (281) 483-1003. Refer to MSC-23881-1.*

## Foil Gas Thrust Bearings for High-Speed Turbomachinery

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A methodology has been developed for the design and construction of simple foil thrust bearings intended for parametric performance testing and low marginal costs, supporting continued development of oil-free turbomachinery. A bearing backing plate is first machined and surface-ground to produce flat and parallel faces. Partial-arc slots needed to retain the foil components are then machined into the plate by wire

electrical discharge machining. Slot thicknesses achievable by a single wire pass are appropriate to accommodate the practical range of foil thicknesses, leaving a small clearance in this hinged joint to permit limited motion. The backing plate is constructed from a nickel-based superalloy (Inconel 718) to allow heat treatment of the entire assembled bearing, as well as to permit high-temperature operation. However, other

dimensionally stable materials, such as precipitation-hardened stainless steel, can also be used for this component depending on application.

The top and bump foil blanks are cut from stacks of annealed Inconel X-750 foil by the same EDM process. The bump foil has several azimuthal slits separating it into five individual bump strips. This configuration allows for variable bump spacing, which helps to ac-