tions are also possible. Blocking makes it possible, during the subsequent analysis of the data, to remove this between-block component of the unexplained variance.

Averaging of genuine replicates causes random errors to cancel. These errors can include what would otherwise be undetectable systematic variations that are converted to random errors by randomizing the loading schedule. Replication also facilitates unbiased estimates of pure error, the component of error attributable to ordinary chance variations in the data. Estimates of pure error enable an objective assessment of the quality of fit of the mathematical model.

Integration of the single-vector hardware system with MDOE techniques has enabled an order of magnitude reduction in wind-tunnel balance calibration time and cost, while simultaneously increasing the quality of the information obtained from the calibration experiment. The SVS provides the basis for further advancement in force measurement technology in the areas of higher-order mathematical models, implementation of statistical process control, and an expansion of the calibration mathematical model to include temperature as an independent variable.

This work was done by P. A. Parker and R. DeLoach of **Langley Research Center**.

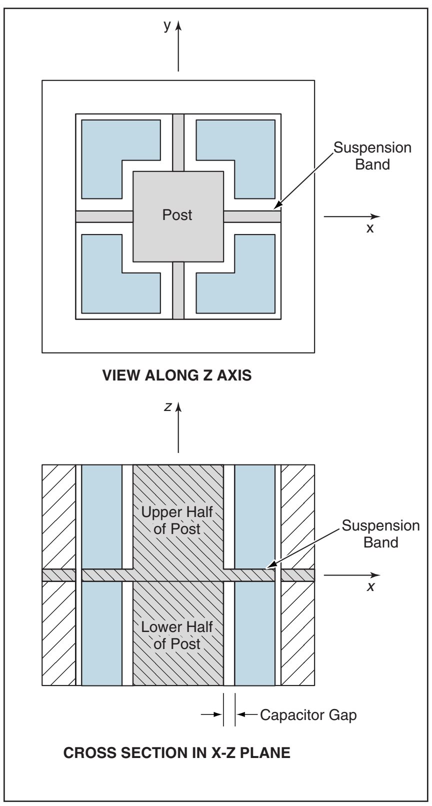
This invention is in the process of being exclusively licensed. Inquiries concerning technical aspects of the invention may be directed to the inventor, Pete Parker, at (757) 864-4709. Inquiries concerning the licensing and commercialization of the invention may be directed to Barry Gibbens of the NASA LaRC Technology Commercialization Program Office at (757) 864-7141.
LAR-16020

Microgyroscope With Vibrating Post as Rotation Transducer

Unlike in prior vibratory microgyroscopes, there is no cloverleaf structure.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure depicts a micromachined silicon vibratory gyroscope that senses rotation about its *z* axis. The rotation-sensitive vibratory element is a post oriented (when at equilibrium) along the *z* axis and suspended at its base by thin, flexible silicon bands oriented along the *x* and *y* axes, respectively. Unlike in the vibratory microgyroscopes described in the immediately preceding article ["Cloverleaf Vibratory Microgyroscope With Integrated Post" (NPO-20688)] and other previous articles in *NASA Tech Briefs*, the rotation-sensitive vibratory element does not include a cloverleaf-shaped structure that lies (when at equilibrium) in the *x-y* plane.



The **Outer Ends of the Post Oscillate** in the *x-y* plane as the suspension bands flex and bend. The oscillations are affected by rotation of the entire device about the *z* axis.

As in the cases of the previously reported vibratory microgyroscopes, vibrations of the rotation-sensitive vibratory element are excited electrostatically, the vibrations are measured by use of capacitive proximity sensors, and the rate of rotation along the axis of sensitivity is deduced from the effect of the Coriolis force upon the vibrations. To create electrodes for electrostatic excitation and capacitive sensing of vibrations, portions of the facing surfaces of the post and of the four stationary members that surround the post are rendered electrically conductive; this can be accomplished by either depositing metal films or else doping the silicon in the affected areas.

In this case, the vibrations in question are those associated with motion of the outer ends of the post in the *x-y* plane, and the axis of sensitivity is the *z* axis. The post is initially driven to oscillation of its outer (free) ends along, say, the *x* axis. Under rotation about the *z* axis, the Coriolis force causes the outer ends of the post to oscillate along the *y* axis also. The rotation-rate sensitivity of the microgyroscope is proportional to the rate of rotation about the *z* axis, the drive amplitude, and the resonance quality factor (Q) of the vibratory element.

Like the vibratory microgyroscope described in the immediately preceding article, this one is fabricated as two micromachined silicon components, which are then bonded together. In this case, the four flexible suspension bands and half of the post are made from one silicon wafer, while the other half of the post is made from another silicon wafer.

This work was done by Tony K. Tang and Roman Gutierrez of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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