A Kinematic Calibration Process for Flight Robotic Arms

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The Mars Science Laboratory (MSL) robotic arm is ten times more massive than any Mars robotic arm before it, yet with similar accuracy and repeatability positioning requirements. In order to assess and validate these requirements, a higher-fidelity model and calibration processes were needed.

Kinematic calibration of robotic arms is a common and necessary process to ensure good positioning performance. Most methodologies assume a rigid arm, high-accuracy data collection, and some kind of optimization of kinematic parameters. A new detailed kinematic and deflection model of the MSL robotic arm was formulated in the design phase and used to update the initial positioning and orientation accuracy and repeatability requirements. This model included a higher-fidelity link stiffness matrix representation, as well as a link level thermal expansion model. In addition, it included an actuator backlash model.

Analytical results highlighted the sensitivity of the arm accuracy to its joint initialization methodology. Because of this, a new technique for initializing the arm joint encoders through hardstop calibration was developed. This involved selecting arm configurations to use in Earth-based hardstop calibration that had corresponding configurations on Mars with the same joint torque to ensure repeatability in the different gravity environment.

The process used to collect calibration data for the arm included the use of multiple weight stand-in turrets with enough metrology targets to reconstruct the full six-degree-of-freedom location of the rover and tool frames. The follow-on data processing of the metrology data utilized a standard differential formulation and linear parameter optimization technique.

This work was done by Curtis L. Collins and Matthew L. Robinson of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-49013

Magnetostrictive Alternator

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This innovation replaces the linear alternator presently used in Stirling engines with a continuous-gradient, impedance-matched, oscillating magnetostrictive transducer that eliminates all moving parts via compression, maintains high efficiency, costs less to manufacture, reduces mass, and eliminates the need for a bearing system.

The key components of this new technology are the use of stacked magnetostrictive materials, such as Terfenol-D, under a biased magnetic and stress-induced compression, continuous-gradient impedance-matching material, coils, force-focusing metallic structure, and supports. The acoustic energy from the engine travels through an impedance-matching layer that is physically connected to the magnetostrictive mass. Compression bolts keep the structure under compressive strain, allowing for the micron-scale compression of the magnetostrictive material and eliminating the need for bearings.

The relatively large millimeter displacement of the pressure side of the impedance-matching material is reduced to micron motion, and undergoes stress amplification at the magnetostrictive interface. The alternating compression and expansion of the magnetostrictive material creates an alternating magnetic field that then induces an electric current in a coil that is wound around the stack. This produces electrical power from the acoustic pressure wave and, if the resonant frequency is tuned to match the engine, can replace the linear alternator that is commonly used.

This work was done by Rodger Dyson and Geoffrey Bruder of Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18939-1.