Mechanics/Machinery

Modular, Rapid Propellant Loading System/Cryogenic Testbed

John F. Kennedy Space Center, Florida

The Cryogenic Test Laboratory (CTL) at Kennedy Space Center (KSC) has designed, fabricated, and installed a modular, rapid propellant-loading system to simulate rapid loading of a launch-vehicle composite or standard cryogenic tank. The system will also function as a cryogenic testbed for testing and validating cryogenic innovations and ground support equipment (GSE) components. The modular skid-mounted system is capable of flow rates of liquid nitrogen from 1 to 900 gpm (≈3.8 to 3,400 L/min), of pressures from ambient to 225 psig (≈1.5 MPa), and of temperatures to –320 °F (≈–195 °C). The system can be easily validated to flow liquid oxygen at a different location, and could be easily scaled to any particular vehicle interface requirements.

This innovation is the first phase of development of a smart Simulated Rapid Propellant Loading (SRPL) system that can be used at multiple sites for servicing multiple vehicle configurations with varying interface flow, temperature, and pressure requirements. The SRPL system can accommodate cryogenic components from ¼ to 8 in. (≈0.6 to 20 cm) and larger, and a variety of pneumatic component types and sizes. Temperature, pressure, flow, quality, and a variety of other sensors are also incorporated into the propellant system design along with the capability to adjust for the testing of a multitude of sensor types and sizes.

The system has three modules (skids) that can be placed at any launch vehicle site (or mobile), and can be connected with virtually any length of pipe required for a complete propellant loading system. The modules include a storage area pump skid (located near the storage tank and a dump basin), a valve control skid (located on or near the launch table to control flow to the vehicle, and to return to the tank or dump basin), and a vehicle interface skid (located at the vehicle). The skids are fully instrumented with pressure, temperature, flow, motor, pump controls, and data acquisition systems, and can be controlled from a control room, or locally from a PDA (personal digital assistant) or tablet PC.

This work was done by Walter Hatfield, Sr. and Kevin Jumper of ASRC Aerospace Corp. for Kennedy Space Center. Further information is contained in a TSP (see page 1). KSC-13460

Compact, Low-Force, Low-Noise Linear Actuator

This actuator has potential uses in military and automotive applications.

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Actuators are critical to all the robotic and manipulation mechanisms that are used in current and future NASA missions, and are also needed for many other industrial, aeronautical, and space activities. There are many types of actuators that were designed to operate as linear or rotary motors, but there is still a need for low-force, low-noise linear actuators for specialized applications, and the disclosed mechanism addresses this need.

A simpler implementation of a rotary actuator was developed where the end effector controls the motion of a brush for cleaning a thermal sensor. The mechanism uses a SMA (shape-memory alloy) wire for low force, and low noise. The linear implementation of the actuator incorporates a set of springs and mechanical hard-stops for resetting and fault tolerance to mechanical resistance. The actuator can be designed to work in a pull or push mode, or both. Depending on the volume envelope criteria, the actuator can be configured for scaling its volume down to 4×2×1 cm^3. The actuator design has an inherent fault tolerance to mechanical resistance. The actuator has the flexibility of being designed for both linear and rotary motion. A specific configuration was designed and analyzed where fault-tolerant features have been implemented. In this configuration, an externally applied force larger than the design force does not damage the active components of the actuator. The actuator housing can be configured and produced using cost-effective methods such as injection molding, or alternatively, its components can be mounted directly on a small circuit board.

The actuator is driven by a SMA -NiTi as a primary active element, and it requires energy on the order of 20 Ws(J) per cycle. Electrical connections to points A and B are used to apply electrical power in the resistive NiTi wire, causing a phase change that contracts the wire on the order of 5%. The actuation period is of the order of a second for generating the stroke, and 4 to 10 seconds for resetting. Thus, this design allows the actuator to work at a frequency of up to 0.1 Hz.

The actuator does not make use of the whole range of motion of the SMA material, allowing for large margins on the mechanical parameters of the design. The efficiency of the actuator is of the order of 10%, including the margins. The average dissipated power while driving at full speed is of the order of 1 W, and can be scaled down linearly if the rate of cycling is reduced. This design produces an extremely quiet actuator; it can generate a force greater than 2 N and a stroke greater than 1 cm. The operational duration of SMA materials is of the order of millions of cycles with some reduced stroke over a wide temperature range up to 150 °C.

This work was done by Mircea Badescu, Stewart Sherrit, and Yoseph Bar-Cohen of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-47991