

additive toward the final stage, which is the output stage.

Prior SMA actuators typically include polymer housings or shells, steel or aluminum stages, and polymer pads between successive stages of displacement-multiplication assemblies. Typical output forces of prior SMA actuators range from 10 to 20 N, and typical strokes range from 0.5 to 1.5 cm. An important disadvantage of prior SMA wire actuators is relatively low cycle speed, which is related to actuation temperature as follows: The SMA wires in prior SMA actuators are typically made of a durable nickel/titanium alloy that has a shape-memory activation temperature of 80 °C. An SMA wire can be heated quickly from below to above its activation temperature to obtain a stroke in one direction, but must then be allowed to cool to somewhat below its activation temperature (typically, to ≤ 60 °C in the case of an activation temperature of 80 °C) to obtain a stroke in the opposite direction (return stroke). At typical ambient temperatures, cooling times are of the order of several seconds. Cooling times thus limit cycle speeds. Wires made of SMA alloys having significantly higher activation temperatures [denoted ultra-high-temperature

(UHT) SMA alloys] cool to the required lower return-stroke temperatures more rapidly, making it possible to increase cycle speeds.

The present development is motivated by a need, in some applications (especially aeronautical and space-flight applications) for SMA actuators that exert higher forces, operate at greater cycle speeds, and have stronger housings that can withstand greater externally applied forces and impacts. The main novel features of the improved SMA actuators are the following:

- The ends of the wires are anchored in compact crimps made from short steel tubes. Each wire end is inserted in a tube, the tube is flattened between planar jaws to make the tube grip the wire, the tube is compressed to a slight U-cross-section deformation to strengthen the grip, then the crimp is welded onto one of the actuator stages. The pull strength of a typical crimp is about 125 N — comparable to the strength of the SMA wire and greater than the typical pull strengths of wire-end anchors in prior SMA actuators. Greater pull strength is one of the keys to achievement of higher actuation force.

- For greater strength and resistance to impacts, housings are milled from aluminum instead of being made from polymers. Each housing is made from two pieces in a clamshell configuration. The pieces are anodized to reduce sliding friction.
- Stages are made stronger (to bear greater compression loads without excessive flexing) by making them from steel sheets thicker than those used in prior SMA actuators. The stages contain recessed pockets to accommodate the crimps. Recessing the pockets helps to keep overall dimensions as small as possible.
- UHT SMA wires are used to satisfy the higher-speed/higher-temperature requirement.

This work was done by Mark A. Cummin, William Donakowski, and Howard Cohen of MIGA Motor Co. for 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: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18267-1.

❁ “Bootstrap” Configuration for Multistage Pulse-Tube Coolers

Lyndon B. Johnson Space Center, Houston, Texas

A “bootstrap” configuration has been proposed for multistage pulse-tube coolers that, for instance, provide final-stage cooling to temperatures as low as 20 K. The bootstrap configuration supplants the conventional configuration, in which customarily the warm heat exchangers of all stages reject heat at ambient temperature. In the bootstrap con-

figuration, the warm heat exchanger, the inertance tube, and the reservoir of each stage would be thermally anchored to the cold heat exchanger of the next warmer stage. The bootstrapped configuration is superior to the conventional setup, in some cases increasing the 20 K cooler’s coefficient of performance two-fold over that of an otherwise equivalent

conventional layout. The increased efficiency could translate into less power consumption, less cooler mass, and/or lower cost for a given amount of cooling.

This work was done by Ali Kashani and Ben Helvensteijn of Atlas Scientific for Johnson Space Center. Further information is contained in a TSP (see page 1).

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❁ Reducing Liquid Loss During Ullage Venting in Microgravity

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A centripetal-force-based liquid/gas separator has been proposed as a means of reducing the loss of liquid during venting of the ullage of a tank in microgravity as a new supply of liquid is pumped into the tank. Centripetal-force-based liquid/gas separators are used on Earth, where mechanical drives (e.g., pumps and spinners) are used to

impart flow speeds sufficient to generate centripetal forces large enough to effect separation of liquids from gases.

For the proposed application, the separator would be designed so that there would be no need for such a pump because the tank-pressure-induced outflow speed during venting of the ullage would be sufficient for centripetal separa-

tion. A relatively small pump would be used, not for separation, but for returning the liquid recovered by the separator to the tank.

This work was done by Bich Nguyen and Lauren Nguyen of The Boeing Co. for Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809. MSC-23230-1