SHAPE MEMORY ALLOY THERMAL SWITCH

Final Report

JPL Task 973

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A. OBJECTIVES

In the year 2000, a DRDF study demonstrated that the shape memory alloy effect could be used to modulate conductivity through a bolted joint to passively provide thermal isolation when a component is cold, and to thermally conduct when a component is hot. The objective of the DRDF study of the year 2001 was to further refine this device to improve its temperature range performance, to amplify the conductivity modulation effect, and to further characterize the device.

B. PROGRESS AND RESULTS

Alloy Selection - Temperature range of performance for shape memory alloy (SMA) is controlled by the alloy used and the stress within the part. A survey of vendors resulted in determining two alloys within the range of desired performance that were affordable, were available, and could be two-way trained within a lead-time that satisfied the testing schedule. Alloy D had unstressed properties to reach full martensitic condition at -278°C and full austenitic condition at 0°C. Alloy X had unstressed properties to reach full martensitic condition at -538°C and full austenitic condition at -158°C. A goal of this study was to select an alloy that would fully develop a flight-level stress in the bolt upon warming to room temperature. By selecting alloys with full austenitic condition temperatures lower than room temperature, the SMA washers have 208°C to 358°C to generate strain that will produce stress within the bolt.

Hardware Modification - Modifications from the first test configuration were made to improve the conductivity modulation effect. The modifications were to add a spring to lift the variable-temperature component off of the cold component when the SMA shrinks; to add insulating washers beneath the head of the bolt, beneath the nut of the bolt, and beneath the spring; and to coat the bottom of the switch body with low-emissivity gold. Figure 1 shows the configuration that was tested. An additional change was to contain each instance of the switch in a body that could be easily assembled to the variable-temperature component.

Testing - A test fixture was assembled that included three variable-temperature base plates with four thermal switches attaching each base plate to one single cold plate. Heaters

totaling about 102 ohms of resistance were attached to each base plate. The thermal switches for each base plate were of three configurations (one type for each base plate) differing by thickness of SMA washers and alloy type for the SMA washers. The three configurations were: Alloy D stacked 0.4" high, Alloy D stacked 0.6" high, and Alloy X stacked 0.6" high. Thermal couples were taped on either side of the thermal switches to enable measurement of conduction through each thermal switch joint.

The test fixture was installed into a vacuum chamber with the cold plate clamped to a nitrogen-cooled heat exchanger. The heat exchanger was cooled to –608°C. Power was applied to the heaters, and the temperature was allowed to stabilize. Once the changes in temperatures were less than 0.18°C every 5 minutes, the current, voltage, and temperature readings were recorded. This data was used to calculate conductance, and was plotted versus temperature. The data is presented in Figure 2, Test Data -- Complete. As can be seen, the data of both the Alloy D, 0.6" SMA increasing temperature case and decreasing temperature case are not well behaved. This could be a result of poor thermal couple attachment or performance. Removing those cases from the data yields the graph shown in Figure 2, Test Data -- Reduced.

C. SIGNIFICANCE OF RESULTS

The test results do not show the effect that was anticipated. The SMA washer made of Alloy X should have reached a full extension sooner than the Alloy D washers, but showed consistently worse conduction performance. The cause of the anomalous readings for the 0.6" Alloy D case needs to be explored. In addition, the SMA washers do not appear to have reached their full extension, since the increasing temperature curves do not appear to be leveling off.

These results indicate that the test setup needs to be carefully examined before proceeding further. The thermal couple attachments, blanketing, and workmanship of the test needs to be evaluated. In addition, further testing is needed that brings the temperature of the SMA washer up to its full extension limit.

D. FINANCIAL STATUS

The total funding for this task was $77,000, all of which has been expended.

E. PERSONNEL

No other personnel were involved.

Figure 1. Thermal Switch Configuration

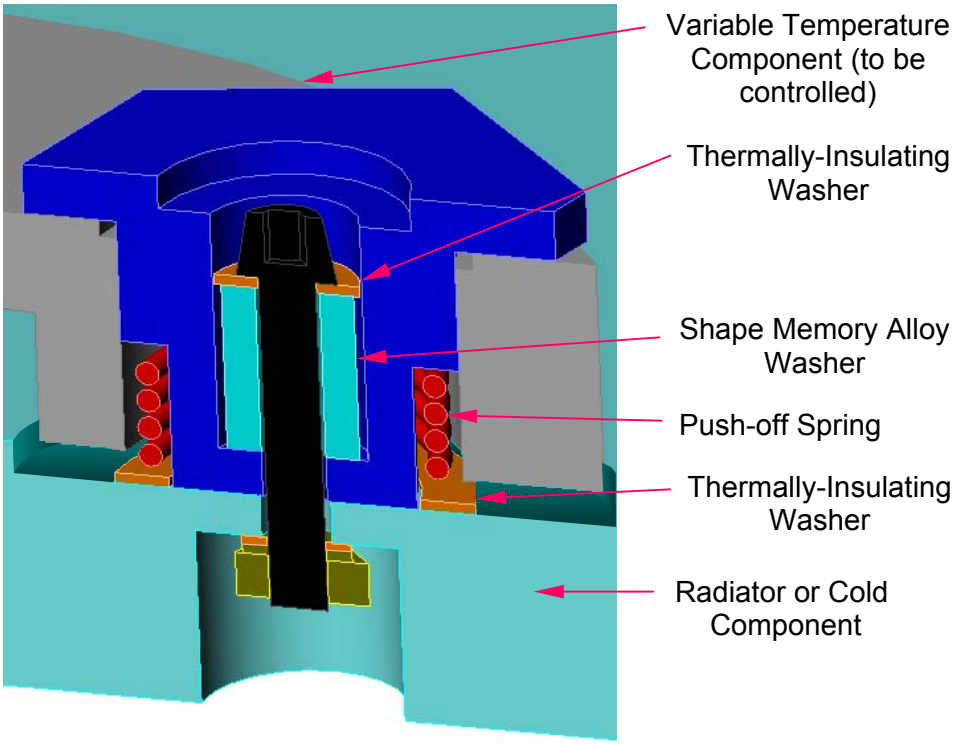


Figure 2.

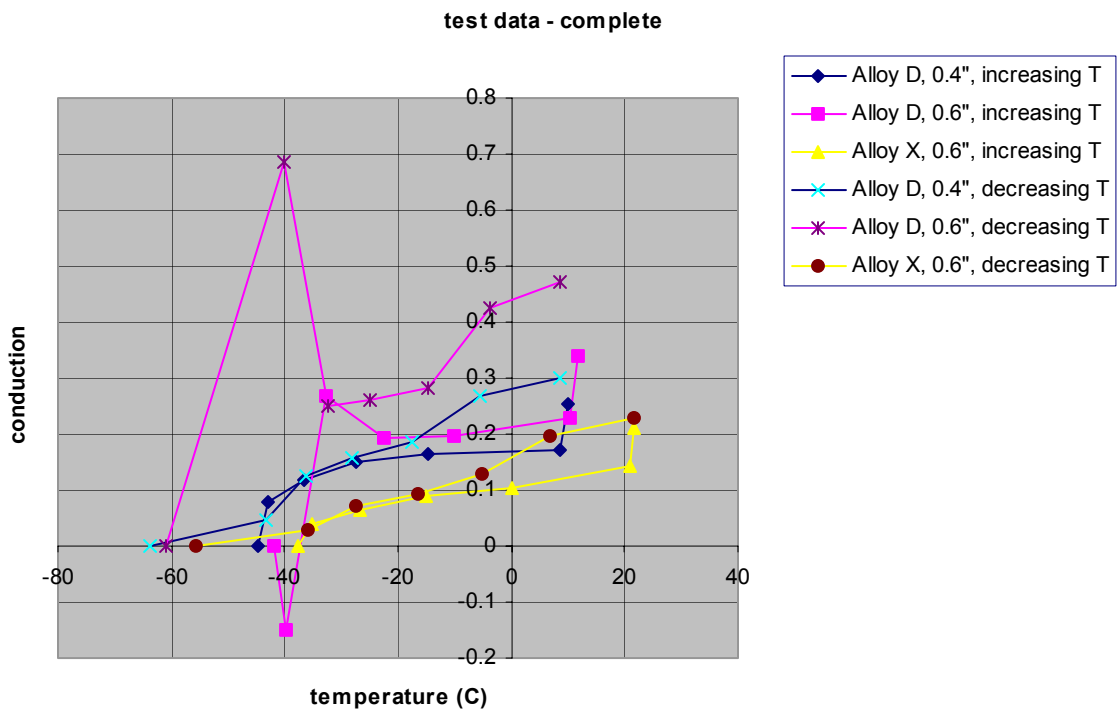
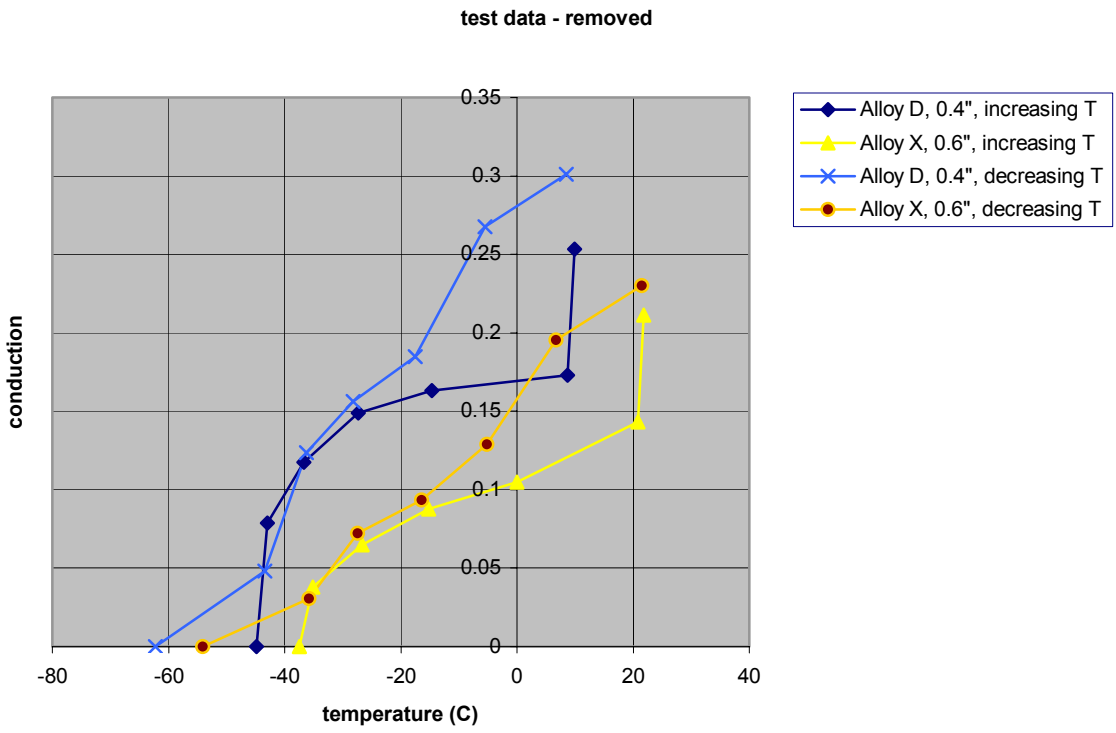


Figure 3.


test data - removed
conduction
temperature (C)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-80
-60
-40
-20
0
20
40
Alloy D, 0.4", increasing T
Alloy X, 0.6", increasing T
Alloy D, 0.4", decreasing T
Alloy X, 0.6", decreasing T