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SHAPE MEMORY METALS

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Final Report

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Abstract

The ability to define a manufacturing process to form, heat-treat, and join parts made of nickel-titanium and/or copper-zinc-aluminum shape memory alloys was investigated. The specific emphasis was to define a process that would produce shape memory alloy parts in the configuration of helical coils emulating the appearance of compression springs. In addition, the mechanical strength of the finished parts along with the development of a electrical lead attachment method using shape memory alloy wire was investigated.

Summary

The main area of investigation associated with this project was to define a manufacturing process for nickel-titanium shape memory alloy helical coil actuators. Development of this manufacturing technique is an important "first step" in the utilization of shape memory alloys as a electromechanical device. The results associated with this project have established the process feasibility to form, heat-treat, and join shape metal alloys in addition to evaluating various welding techniques to attach an electrical lead to a shape metal alloy wire.

Discussion

Scope and Purpose

This work was performed to develop the capability to form, heat-treat, and join nickel-titanium shape memory alloy into a helical coil configuration of varying diametrical sizes. The development of this manufacturing process is an important step in the use of shape memory alloys in stronglink devices. Using shape metal alloys in stronglink devices has the advantage of a much greater output force to volume ratio than the present stronglink driving technology (rotary solenoids). Replacement of stronglink solenoids with a shape memory alloy configuration would enable future stronglinks to be packaged in a much smaller volume and nuclear safety would be enhanced due to the energy conversion associated with shape memory alloys.

Activity

The main activity associated with this project was the development of a fabrication process to form, heat treat, and join nickel-titanium shape memory alloy helical coils for use as mechanical actuators. Tooling, fixturing, and various manufacturing processes were developed to wind compression and extension springs using a mandrel lathe. The desired final configuration of the springs was achieved by development of heat-treat fixtures and associated process techniques. The heat treated shape memory alloy coils were attached to end fittings by a swaging process developed through the efforts supported by this project. The finished shape memory alloy springs attached to the end fittings were submitted through a pull test so that a baseline on the

mechanical strength associated with the joining process could be characterized.

A sample number of the shape memory alloy helical coil springs was submitted through an evaluation to characterize the force vs. displacement response when exposed to varying temperatures. The investigation on the dynamic response of shape memory alloy springs was to determine their feasibility as a type of mechanical actuator used in stronglink devices. This characterization was discontinued when personnel changes halted the efforts.

Since the publication of the topical report An investigation of welding a nickel wire and a gold-plated nickel ribbon to a shape metal memory wire emulating an electrical lead attachment was performed. This type of an electrical attachment is used in many stronglink devices.

Several welding methods were investigated to achieve the attachment of an electrical lead to a shape memory alloy wire. The following processes were attempted: percussive arc butt, cold weld forge welding, pulse arc fusion welding, and resistance butt welding. In each of the four welding processes, the objective was to join a solderable nickel

Of the four welding processes, only the resistance butt weld produced a consistent maximum tensile strength joint. The other three welding techniques resulted in joint strengths ranging from minimal strength to 50% of the nickel wire strength. The resistance butt weld joints achieved the tensile strength of the nickel wire. The mode of failure associated with this welding technique was in the nickel wire away from

the joint. The weld engineer who performed the evaluation suggested that because these results are based on a small experimental quantity of parts, a more comprehensive study should be performed before the implementation of this technique. The resistance butt weld process can be seen in Figure 1.

The pulse arc weld has potential as an attachment method since the mechanical strength of the weld is achieved by wrapping the nickel wire around the shape memory alloy wire prior to welding as shown in Figure 2. Determining which specific joining processes to use will greatly depend on the specific application since each welding method requires different access to the shape memory wire during the welding process. Metallurgical cross-sections of the pulse arc and resistance butt welds are shown in Figures 3 and 4.

Although this weld evaluation resulted in two potential weld processes for joining nickel wire to a shape memory alloy wire, the evaluation did not address other important factors regarding the choice of which welding technique is most suitable for the specific application. The factors which must be considered and investigated before implementation of a specific weld process are

- metal chemistry,
- high and low temperature stability, and
- long term joint stability.

Accomplishments

A fabrication process for nickel-titanium shape memory alloy helical coil actuators was successfully developed through the efforts and funding supported by this project. Nickel-titanium shape memory coils were fabricated to evaluate their

potential as mechanical actuators and to determine processing variables on actuator outputs. Various welding techniques for attaching electrical leads to a nickel-titanium shape memory metal wire were investigated. This investigation resulted in two potential welding processes with the capability of producing an adequate weld joint.

Figure 1. Weld Process Associated
With the Resistance Butt Weld

Figure 2. Weld Process Associated With the Pulse Arc Weld

Figure 3. Cross Section of a Pulse Arc Weld Between a 0.03 in. Diameter Shape Memory Metal Wire and a 0.01 in. by 0.02 in. Nickel Ribbon (50x)

Figure 4. Cross Section of a Resistance Butt Weld Between a 0.050 in. Diameter Shape Memory Metal Wire (left) and a 0.03 in. Diameter Nickel Wire (right).

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