2006-608: MEMORY METALS

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Memory Metals

There are two very common ways to create motion from electricity - motors and solenoids. Most of the equipment and machines found in homes, factories and offices today make extensive use of these two devices. Both motors and solenoids rely on magnetic fields to produce the mechanical motion that is utilized for linear and rotary power transmission.

Due to recent advancements in memory metals, another method of creating motion has become available that does not rely on magnetic fields. Memory metals are special metals that undergo changes in shape and hardness when heated or cooled, and do so with a great amount of force. The most widely utilized memory metal is nitinol and is a "nearly equal mixture of nickel and titanium."[1]

When made into wires, memory metals can be stretched by as much as eight percent when below their transition temperature, and when heated, they will recover their original, shorter length. This is referred to as the materials "deformation-to-recovery ratio". During the temperature dependent *bysteresis,* a usable amount of mechanical force is developed.

Memory metals are fascinating alloys that are included in a relatively new branch of material science that is comprised of substances that respond to the application of an external force with a change in shape or state. These materials often carry titles such as intelligent materials, active materials, shape memory alloys, or adaptive materials.

Many of these materials develop enough usable force during their transition to power small linear actuators and motors. Conversely, some of these materials can also be used as sensors where a strain applied on the material is transformed into a signal that allows computation of the strain levels in the system. "The amount of actuation force depends on a large number of factors. The most important are geometry of the actuator, cross section of the used shape memory alloy, and the amount of stress in the actuator." [2]

Rather than exhibiting a shape change, other materials demonstrate unique properties such as change of state. Electro- and magneto-rheological fluids, for example, can change viscosity over many orders of magnitude upon application of an external magnetic or electric field. This change of state has the potential to revolutionize the control aspects and responsiveness of hydraulic power transmission.

Research during the 1960's and 70's was focused on devices such as: satellite antennas (NASA) that would unfold and expand when exposed to the heat of the sun; engines that would run on hot and cold water; automatic temperature-controlled greenhouse windows; and car fan clutches that would engage only when the engine warmed-up.

One of the primary applications of memory metals today is in the medical arena with devices such as filters that are inserted into a patient's vein or artery to trap stroke-causing blood clots. It is inserted cold, and as it warms, it opens to form a filter. Other applications include highly reliable coupling connections for aircraft hydraulic lines, air valves, fuse protectors, and even a six axis computer-controlled robotic arm!

The objective of the following memory metal demonstration is to observe and gain an understanding of an unusual crystal alloy that radically transitions to a different structure at a distinct temperature and recovers to the pre-deformation shape. It is interesting to note that educational robots are available that use a memory metal "alloy actuator wire that expands and contracts, roughly emulating the operation of a muscle. The application of heat (provided by a controlled pulse of electricity) causes a crystalline structure change in the wire." [3]

Needed Equipment include: Nitinol wire; mounting board; two AA batteries with holder and connecting wires; elastic band; two push pins; empty plastic milk jug.

1. Cut a strip of plastic from the milk jug that measures three- quarters of an inch by three and one-half inches to form the lever arm and make two holes in it with the pushpin. The first hole should be three-eighths of an inch from the end, and a second hole three-quarters of an inch from the same end.

2. Mount the lever arm on the cardboard by inserting the pushpin into the first hole. This is the pivot point of the lever.

3. Attach a four inch length of Nitinol wire to the second hole and, using the second pushpin, attach the other end of the Nitinol wire to the mounting board to position the lever slightly below horizontal.

4. The elastic band will serve as our "load" and is attached to the opposite end of the lever.

5. Connect the two "AA" batteries (in series) and briefly apply power to each of the ends of the Nitinol wire.

6. After observing the movement, remove the power quickly and observe the recovery.

Several forms of data collection are possible from this type of experiment. One data set can be the deformation-to-recovery ratios at various lengths of Nitinol wire. Other interesting data sets that can be collected and analyzed include mechanical advantages, loads, and lever calculations.

Deformation-To-Recovery Ratio			
	Inactivated	Activated	Ratio
	Length	Length	
Sample One			
Sample Two			
Sample Three			
Sample Four			

Bibliography

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3. Robots and Stuff, http://www.e-clec-tech.com/stkicso.html, downloaded on January 2, 2006.