A Look at Shape Memory Alloy Actuators

A general-purpose globe valve actuator using shape memory alloy (SMA) technology has been recently introduced to the industry. The introduction of this actuator was spurred on by a need in the energy sector for alternatives to methane-venting pneumatic equipment. The operation of venting pneumatic equipment that runs on pressurized methane, or fuel gas, is prevalent at natural gas well sites and facilities. Applications where the operation of pneumatic valve actuators and associated controllers vent methane into the atmosphere, include separators, gas injection, and blanket gas. With impending regulations that disallow the use of methane venting devices, the natural gas industry is challenged to find suitable non-emitting alternatives.

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The Science of Shape Memory Alloys

Shape memory alloys (SMA) are a unique class of metal alloys that can be engineered to remember a specific physical shape. By harnessing this two-way shape memory effect, the shape of the material can be precisely controlled in a repeatable and predictable manner.

An assembly of SMA wires that work against a mechanical compression spring creates the basis for an SMA bundled wire actuator. By passing electric current through the SMA wires a shape memory effect is induced, which overcomes the spring force and causes the SMA wires to contract. When the actuator is coupled to the stem of a valve, the valve's position can be controlled, Figure 2.

Figure 1: The KVA, an SMA bundled wire actuator, deployed at a natural gas production facility near Edson, Alberta.

Unique Features of Shape Memory Alloy Actuators

Fewer Parts, Single Moving Component

A distinction between an SMA bundled wire actuator and traditional motorized actuators is that the SMA bundled wire actuator has one moving part in its driveline. Globe valves controlled by motorized actuators require several components to translate the rotary motion generated by the motor to the linear motion of the valve stem. As a result, motorized actuators can exhibit backlash and require periodic maintenance such as lubrication or component replacement due to wear. The motorless design of the SMA actuator allows for minimal wear on mechanical components allowing for maintenance-free operation.

Mechanical Spring for Failure Closed

Like pneumatic actuators, an SMA bundled wire actuator uses a mechanical spring that is inherent to its design. The mechanical spring permits the SMA bundled wire actuator to return the valve to a known position in the event of power failure. The predictability of systems under failure events is an important property for many processes, especially for sites and facilities in remote locations where power can be unreliable. Though this behavior can be replicated with electric motors using a battery or capacitor as a power source backup, a limitation of this design is that the reliability of such systems is dependent on the proper functioning of the motor, the battery or capacitor backup, and associated controls that must detect and correctly respond to the fault condition. The feature can also be replicated in specialized motorized actuator designs that incorporate a pre-loaded spring.

This method however requires the use of active electrical clutches and brakes that need to be continuously powered. This may not be viable where power resources are limited.

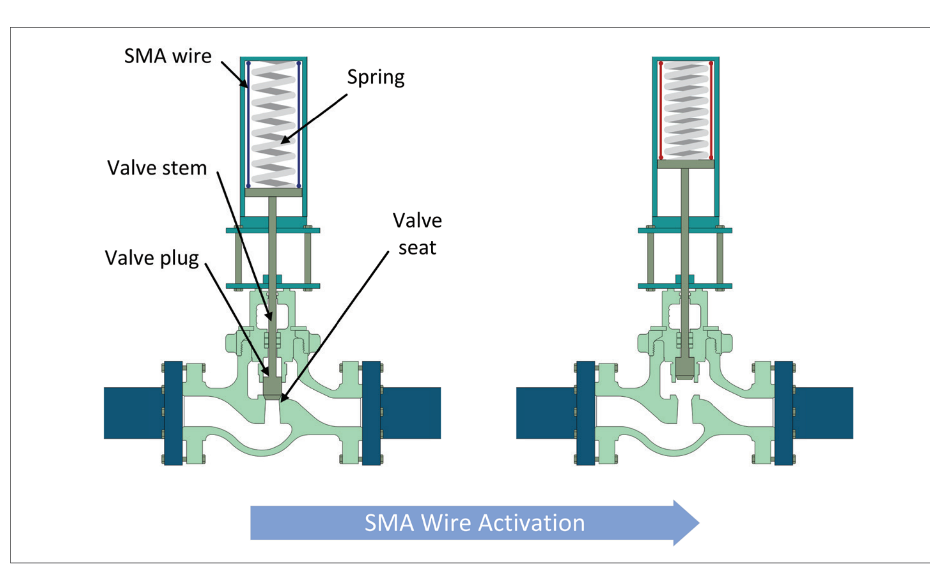

Figure 2: Shape memory alloy in valve actuator application.

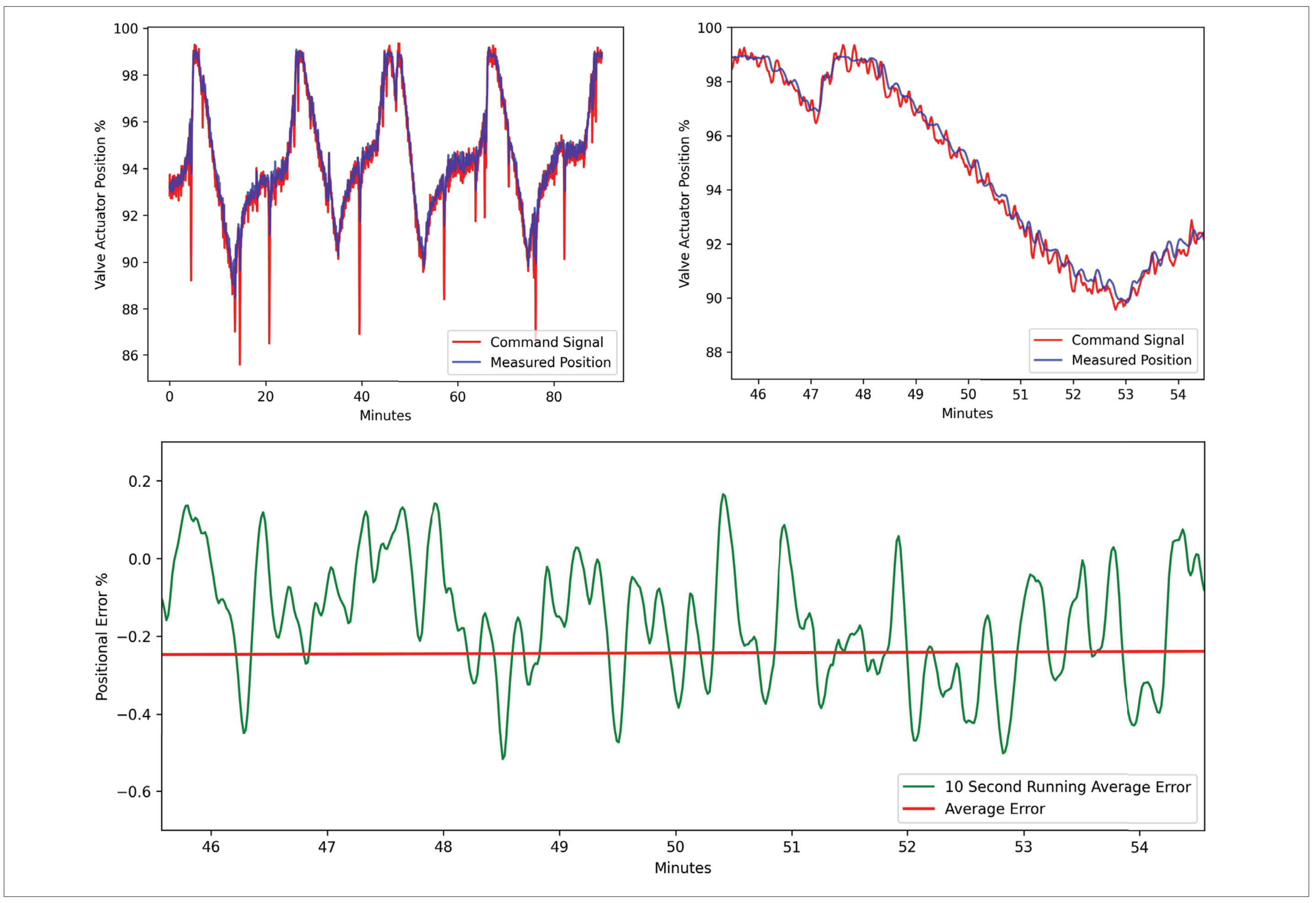

Figure 3: Performance of a field-deployed SMA bundled wire actuator in a continuous modulating/throttling backpressure valve application at a natural gas production facility, the absolute average error was less than 50 µm [.002 inch].

Continuous Motion

The ability for continuous motion or valve throttling can be achieved with SMA bundled wire actuators without limitations typical of motorized systems. Motorized systems (i.e., electric-motor actuators or air compressors) require periods of rest between operations to prevent damage caused by overheating or wear to components. A common strategy that mitigates continuous operation in motors is to introduce deadband, a period of intentional non-responsiveness to small motion commands. Employing this strategy, however, results in lag or system latency, which can manifest into positional error and instability in process control applications.

SMA bundled wire actuators can run continuously with a 100% duty cycle and can immediately respond to commands without deadband limitations. The motion developed by the actuator is smooth and responsive to changes in position command. The length of the SMA wires can be controlled to a fine degree, enabling SMA bundled wire actuators to achieve positional precision of under 50 microns (0.002 inch).

Scalable and Flexible

SMA bundled wire actuators can be adapted to meet a wide range of applications and use cases. The actuator's force, travel, and idle position can be engineered to suit a variety of valve sizes, types, and applications. Additionally, SMA bundled wire actuators can be configured to work with either AC (alternating current) or DC (direct current) power at industry-typical voltage levels (eg. 24 VDC or 120 VAC), allowing them to be integrated into facility infrastructure or remote locations that have limited power options.

Performance Testing and Field Trials

Faced with the challenge of transitioning away from methane venting pneumatic equipment, an SMA bundled wire actuator was developed by Kinitics Automation for the Canadian natural gas industry.

The development of the SMA bundled wire actuator included third party lab testing and field trials with partners including the University of Calgary and major natural gas producers in Canada. Testing and field trials of the product were crucial for validating its performance in extreme environments typical of industrial applications within the sector.

Third party testing of the actuator was conducted at the NGIF Emissions Testing Centre (ETC) Lab at the University of Calgary. Testing at the ETC was aimed to assess the positioning performance of the actuator under different environmental temperature conditions and its capability to generate sufficient force for sustaining a pressure differential across a closed valve. Testing was conducted in environments between -43 °C and +46 °C to validate the actuator's performance at temperature extremes. The actuators' ability to generate closing force was verified under gas pressure. Testing of positional performance found the deadband to be smaller than 0.25% (50 µm) and positional accuracy was found to be within 0.1% (19 µm) across all temperature conditions.

The SMA bundled wire actuator was certified to operate in both ordinary and hazardous locations (Canada & US Class I, Zone 1 AEx db IIAT6 Gb) and has been deployed at various operational sites of major natural gas producers for field trials including a Tourmaline Oil Corp. natural gas production well site near Edson, Alberta, Figure 1. Three actuators were deployed on a test separator at this site with one actuator used for backpressure control, a continuous throttling application, and two actuators for snap action level control. The actuators were installed in late 2022 and data shows the actuators to have high uptime and high positional performance. Data acquired from the backpressure control valve showed an average error of less than 0.5% during a 12-day period where the valve was in a constant throttling mode, Figure 3.

The field site employed a natural gas generator that produced electric power for the site's facility and equipment. A power system fault occurred in February 2023 that resulted in a power outage. During this time, a battery-powered data acquisition system was able to capture the behavior of the SMA bundled wire actuators during this power loss event which showed that the actuators were able to move into and hold a closed position when unpowered.

Conclusion

The introduction of an SMA bundled wire actuator presents the industrial valve sector with a new method of valve control. The use of SMA technology allows for reduced maintenance requirements, improved accuracy and reliability, and electric control with spring closure. Rigorous lab testing and real-world field trials validate the technology for durability in industrial environments. The introduction of SMA bundled wire actuators indicates a promising future for SMA technology, underlining its potential to redefine principles for industrial valve actuators and help pave the way for a more sustainable energy sector.

ABOUT THE AUTHOR

Adam Nguyen is an Automation Solutions Specialist at Kinitics Automation. He is dedicated to pushing the boundaries of technology in robotics, computer vision, and industrial automation. His commitment to innovation fuels his work, with a goal for a more advanced and sustainable world through cutting-edge solutions.