Smart and Energy-efficient Actuators based on Shape Memory Alloys and Dielectric Elastomers

Intelligente und Energieeffiziente Aktoren basierend auf Formgedächtnislegierungen und Dielektrischen Elastomeren

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Kurzfassung

In times of a general widespread demand for more functionality in products and at the same time growing restrictions, engineers are faced with more complex and challenging design tasks. For the development of novel or improved products, more and more engineers start looking into smart materials to replace state-of-the-art actuators or sensors or to design new multifunctional and intelligent actuator-sensor-systems. Smart or active materials like shape memory alloys (SMAs) or electro-active polymers (EAPs) change their properties in response to external fields. These property changes can either be exploited to produce movement and force for actuation or for quantitative measurements like a specific sensor. Aside from their combined actuation and sensing capabilities, smart materials can offer significant savings in weight and construction space because of their high energy and power densities. Actuator systems based on smart materials have the potential to generate very energy-efficient solutions in comparison to electric, electromagnetic, hydraulic or pneumatic actuators and operate without noise and emissions. The materials’ specific and flexible form factors enable completely new actuator designs and implementation and current topics of interest such as predictive maintenance and condition monitoring can be addressed by using their sensing abilities. Even further, this “self-sensing” may be utilized in control algorithms for closed-loop position control without the use of additional external sensors.

This work has a specific focus on making actuators based on SMAs and dielectric elastomers (DEs) energy-efficient and demonstrating their properties in exemplary applications. In the first part, a novel bi-stable SMA actuation principle [1-3] is introduced. The actuator is based on SMA wires, which when heated to a specific transformation temperature undergo a phase transformation. The phase transformation causes a contraction of the SMA wire of several percent and the actuator is able to perform mechanical work. SMAs have the highest known energy density of all known actuation principles [4], which leads to very compact and lightweight design solutions. The bi-stability in this actuator leads to significant savings in energy consumptions compared to state of the art SMA actuators. This actuation principle is then exemplary used in the application of a vacuum gripper system. In this system, SMA actuators control and drive suction cups so that no compressed air system is needed [5].

The second part introduces the principle of dielectric elastomer actuators. Electrically, these actuators present a deformable capacitor. Actuation is achieved by loading and unloading this capacitor, which also leads to two quasi energy-free states [6]. Like SMAs, DE actuators (DEAs) show a lot of promise to reduce construction space and weight in applications. Compared to SMA actuators, which are known for high forces but limited actuation frequency (1-10 Hz), DEAs can be activated up to several kHz, but in a lower force region. The potential of DEAs is displayed at the application example of a pneumatic valve. In a first step, a commercial electromagnetic valve is evaluated in a typical work cycle and the pneumatic characteristics and the energy consumption are documented. The electromagnetic drive in the valve is then replaced by a DEA and the same working cycle is used for its characterization. Comparison between the two valves shows identical pneumatic performance, while the DE valve’s energy consumption is reduced by a factor of 500 [7].
Fig. 1: Bi-stable SMA based vacuum suction cup attached to a robot (left) and the DEA driven pneumatic valve (right).

Literatur


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