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Rolf Gaasbeek and Bram de Jager
Eindhoven University of Technology, Department of Mechanical Engineering, P.O. Box 513, 5600 MB Eindhoven, The Netherlands.
Email: R.I.Gaasbeek@tue.nl *

1 INTRODUCTION

In micro-robotics, active materials are used to construct extremely small actuators. If requirements on force and/or stroke are challenging, a logical candidate material is Shape Memory Alloy (SMA). By manipulating stress or temperature, the crystallographic structure of SMA can change, resulting in significant strain effects.

The SMA actuators considered in this work are constructed using pre-stressed SMA wires. By manipulating the temperature, an actuating effect is obtained. As temperature rates are limited, the actuation speed of the SMA actuator is limited. The latter, in combination with the inherent hysteresis present in SMA actuators, are the main challenges in obtaining high performance for SMA actuators in general.

In Figure 1, temperature and strain data for a full actuation cycle of a bias-spring actuator set-up [1], is depicted. Strong hysteresis is present, as the crystallographic structure changes at a significantly higher temperature when heating, compared to the low transition temperatures in case of cooling. If the material is overheated (dark grey region), thermal energy is added even after full transition is achieved. Note that, heating after full transition is undesired as the thermal energy has to be removed when an opposite movement of the actuator is required. The latter, due to the limited temperature rate, significantly slows down the actuation speed of the actuator. Following the same reasoning, overcooling (light grey region) is undesirable as well.

Input modifications have been proposed in an attempt to prevent over- and underheating (grey areas in Figure 1). Specifically, modifications based on temperature [3], power or resistance are documented [2].

Unfortunately, the bounds at which over-heating and -cooling occurs, depend on the fraction of transformed material. This fraction is known to be both stress and temperature dependent [1]. Therefore, current methods do not suffice when load is applied, which is typically the case in practical applications.

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In this work it is proposed to use the Novak model [1] to estimate the fraction of transformed material based on resistance, temperature and stress. Additionally, fraction-based input constraints are applied to the input to prevent over-heating and cooling. As an extension to [1], the method is not only compared to a benchmark feedback controller but also with the temperature-based input modifications proposed in [3].

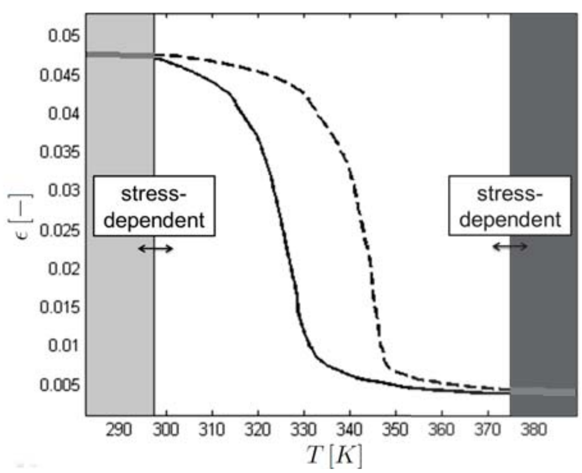

Figure 1: Temperature-strain curve SMA actuator; dashed line: heating, solid line: cooling.

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