Control of a Magnetostrictive Actuator with Application to Micropositioning

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Introduction

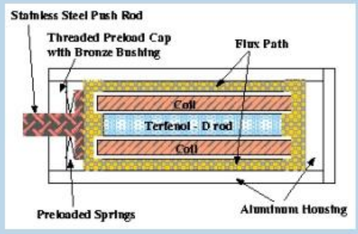
Magnetostriction:

Some ferromagnetic materials (e.g., Terfenol-D) have the following properties: strains are generated in response to an applied magnetic field; Mechanical stresses in the materials produce measurable changes in magnetization. This phenomenon can be used for actuation and sensing.

Applications:

Flight control, Machine control, Micro-positioning, Ultrasonics, Robotics, Vibration control, etc.

The Terfenol-D actuator and the LVDT sensor



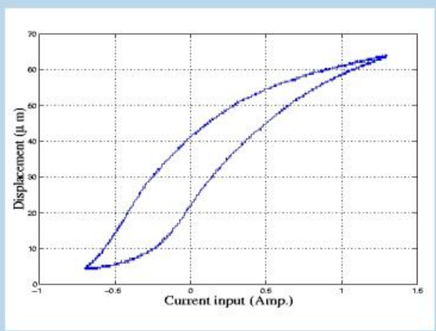
Sectional view of the Terfenol-D actuator (by Etrema)

Micropositioning Control Problem:

Given a desired position of the actuator head, find the input current in the coil, such that the final value of the actual position matches the desired one.

Challenge:

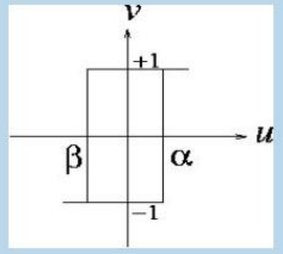
The hysteretic behavior exhibited by magnetostrictive actuators presents a challenge for control.



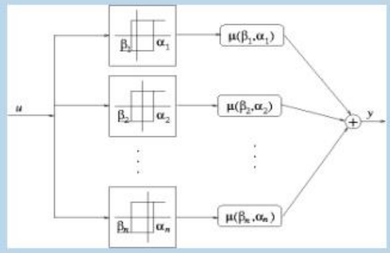
Hysteresis in the magnetostrictive actuator

Value Inversion Approach

- The Preisach operator is used to model the hysteresis and the original control problem is formulated as a value inversion problem for the Preisach operator
- The discretized Preisach operator is treated as a finite state machine (FSM), and the value inversion problem is transformed into a state reachability problem for the FSM
- A state space reduction scheme is proposed to save storage space and computation time
- An algorithm is developed to generate the best representative state in each equivalent class of states

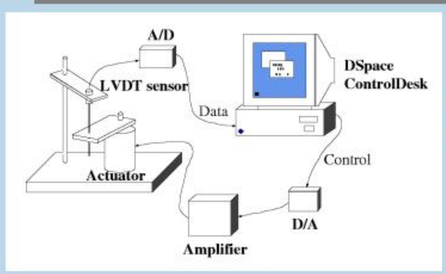


An elementary hysteron

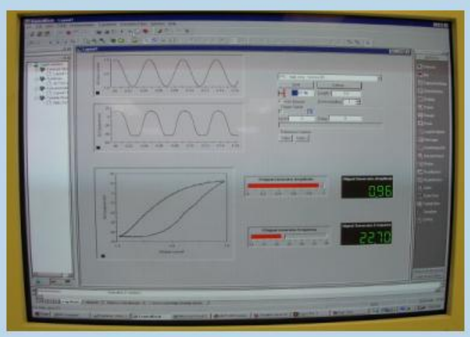


A (discretized) Preisach operator

Experimental results

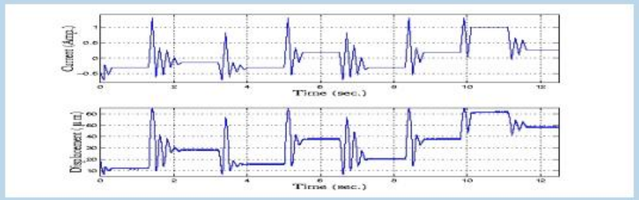


Experiment setup

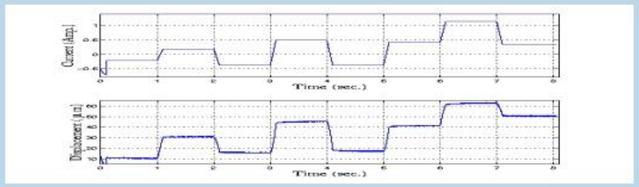


Dspace ControlDesk

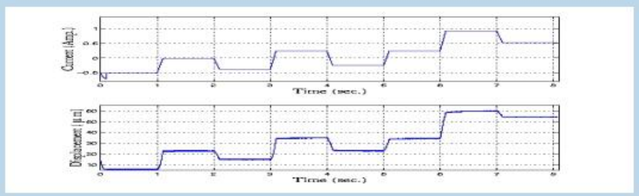
Given a sequence of 8 desired displacement values: 10, 30, 15, 40, 20, 40, 60, 50 (in microns), three schemes have been implemented to achieve the positioning goal.



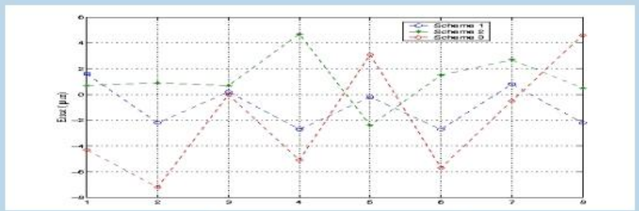
Scheme 1: the value inversion approach



Scheme 2: the trajectory inversion approach [1]



Scheme 3: based on a nonhysteretic model



Comparison of positioning errors

- Scheme 1 is better than Scheme 2, since as a trajectory inversion scheme, the latter does not allow input reversals for each desired value and has less control freedom than Scheme 1 does.
- Scheme 3 delivers the worst performance since the hysteretic behavior is not taken into account.

References:
[1] X. Tan, R. Venkataraman, P. S. Krishnaprasad, " Control of hysteresis: theory and experimental results", Proc. Of SPIE, vol. 4326, pp. 101-112

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