

Effect of model inaccuracies on implementation of control strategy for shape memory alloy based actuators



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INTRODUCTION SHAPE MEMORY ALLOY (SMA) **SHAPE MEMORY EFFECT ACTUATION! ORIGINAL SHAPE FORCE DEFORMED SHAPE** COOLING ORIGINAL SHAPE **APPLICATION** MOTIVATION NONLINEARTITY **CONSISTENT & ACCURATE SMA HYSTERESIS MODEL PARAMETER UNCERTAINTY REAL TIME CONTROL POPULAR AMONGST** L.C BRINSON'S MODEL **CONTROL RESEARCHERS SEVERAL INCORRECT PARTIAL LOOP PHENOMENOLOGICAL** RESPONSES, INADMISSIBLE VOLUME FRACTION VALUES IN CERTAIN **MODELS AVAILABLE** "THREE SPECIES **NEAR TO ACCURATE,** MODEL" **CONVENIMENT TO DESIGN MODEL FOR CONTROL** S. M SRINIVASAN et al **IMPLMEMENTATION** BRINSON'S MODEL Hysteretic behavior — Phase Kinetics Load = 2 Kg = 266.476 MPa • Martensite volume fraction — Temp. and stress components

Temperature °C

• Cosine hardening law used. Linear hardening

used for simulation

MODEL INACCURACIES

SOLUTION

OVERSHOOT PROBLEM

BRINSON'S MODEL

OCCURS FOR A COMPLICATED SEQUENCE OF HEATING & COOLING:

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OLIVER PATH: I-2 HEATING, 2-3 COOLING, 3-4 HEATING.

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- DESIRED TRAJECTORY FOR 2ND PATH: 1-2 HEATING, 2-3a COOLING, 3a-4 HEATING.
- THE SUDDEN JUMP FROM 3A TO 3-B IS THE OVERSHOOT.

Temperature °C

● OVERSHOOT → ERRONEOUS CONTROL SIGNAL CALCULATIONS → DELAYED ERROR CONVERGENCE AND TRACKING OF INPUT.

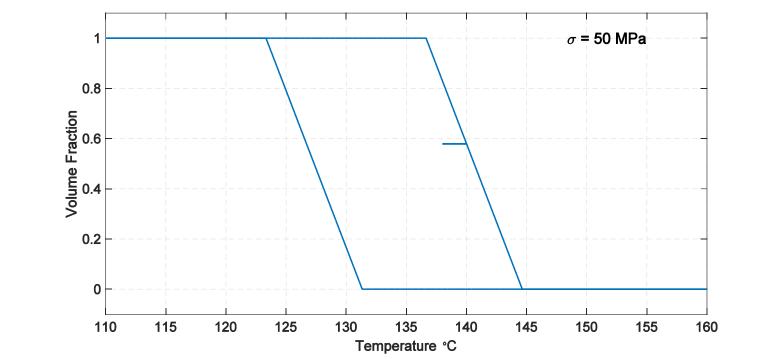
RATCHETING PROBLEM

OCCURS FOR A RECURRENT SEQUENCE OF HEATING & COOLING WITHIN A TRANSFORMATION REGION.

COOLING, 3a-3b-4 HEATING.

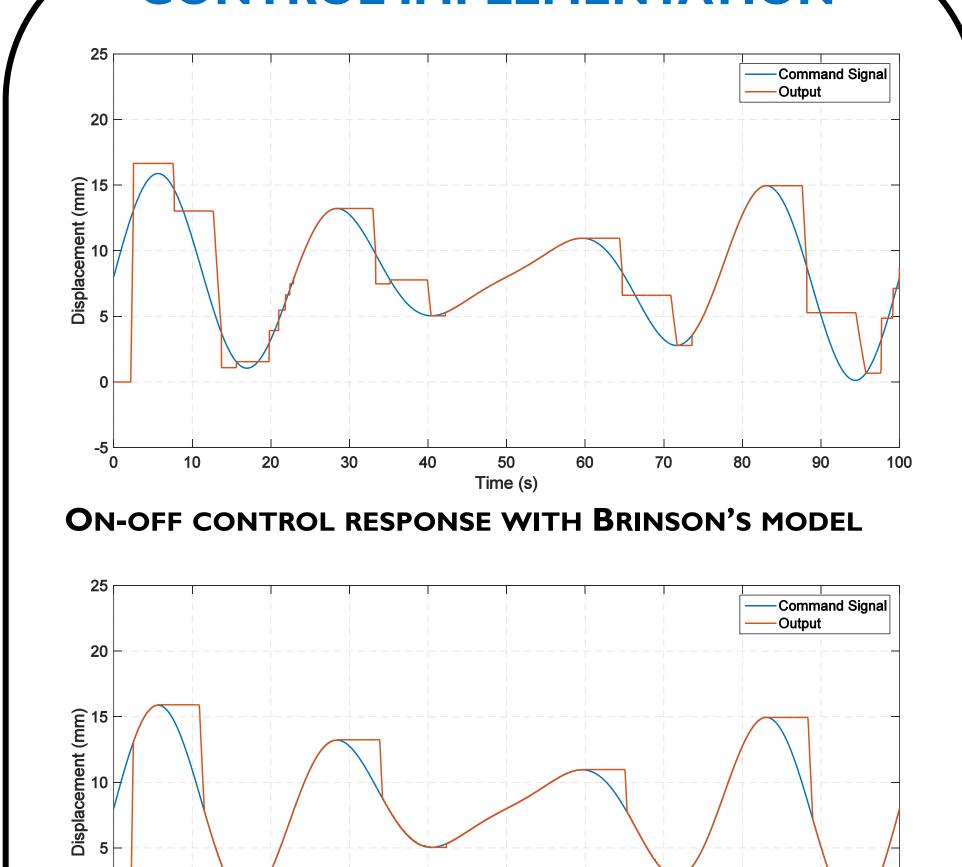
- A-B: RECURRENT COOLING
- C-D: RECURRENT HEATING.
- IDEALLY, RECURRENT HEATING/COOLING CYCLES SHOULD NOT CHANGE THE VOL-UME FRACTION.
- However for each recurrent cycle a new slope is calculated and the volume fraction finally reaches to its extreme values.
- DIFFICULT FOR A CONTROL LAW TO MAINTAIN A SET POINT VALUE.

3 SPECIES MODEL



FOR ANY PARTIAL OR COMPLEX THERMOMECHANICAL PATH THE CURVE ALWAYS RETURNS TO THE PRIMARY MAJOR HYSTERESIS LOOP

CONTROL IMPLEMENTATION



CONCLUSION

BRINSON'S PHENOMENOLOGICAL —— INCORRECT RESPONSES FOR COMPLEX THERMOMECHANICAL PATHS

(OVERSHOOT & RATCHETING)

HODEL

THREE SPECIES MODEL

SOLUTION

INCREASES BURDEN ON CONTROL ALGORITHM

REFERENCES

ON-OFF CONTROL RESPONSE WITH 3 SPECIES MODEL

- [1] Madill, D., Wang, D., "Modeling and L₂-stability of a shape memory alloy position control system," IEEE Trans. Contr. Syst. Technol. 6(4), 473–481 (1998).
- [2] A. K Nallathambi, S. Doraiswamy, A. S Chandrasekar, S. M. Srinivasan, "A 3-species model for shape memory alloys," International Journal of Structural Changes in Solids 6(1), 149-170 (2009).