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

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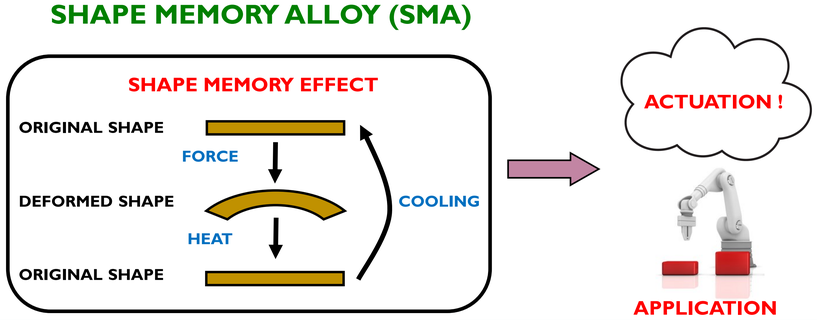
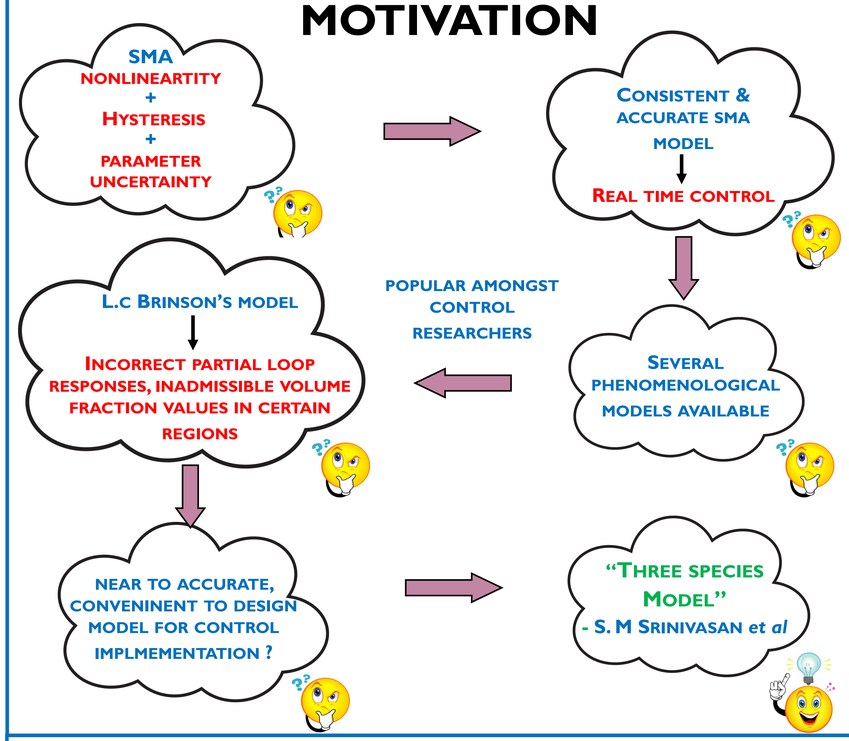
INTRODUCTION

SHAPE MEMORY ALLOY (SMA)

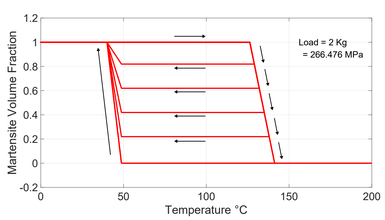


MOTIVATION



BRINSON'S MODEL

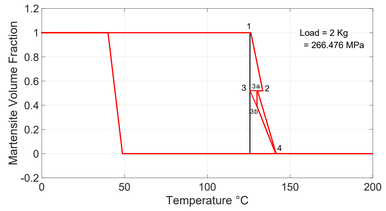
- Hysteretic behavior → Phase Kinetics
- Martensite volume fraction → Temp. and stress components
- Cosine hardening law used. Linear hardening used for simulation



MODEL INACCURACIES

OVERSHOOT PROBLEM

BRINSON'S MODEL



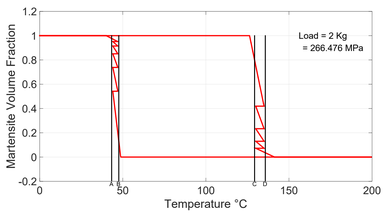
OCCURS FOR A COMPLICATED SEQUENCE OF HEATING & COOLING:

- 1st PATH : 1-2 HEATING, 2-3 COOLING, 3-4 HEATING.
- 2st PATH : 1-2 HEATING, 2-3a COOLING, 3a-3b-4 HEATING.

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

RATCHETING PROBLEM

BRINSON'S MODEL



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

- A-B : RECURRENT COOLING
- C-D : RECURRENT HEATING.

- IDEALLY, RECURRENT HEATING/COOLING CYCLES SHOULD NOT CHANGE THE VOLUME FRACTION.
- HOWEVER FOR EACH RECURRENT CYCLE A NEW SLOPE IS CALCULATED AND THE VOLUME FRACTION FINALLY REACHES TO ITS EXTREME VALUES.

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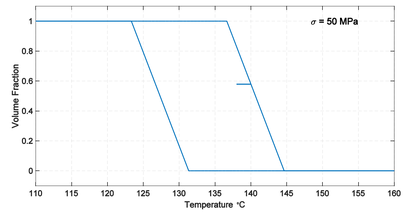
- DIFFICULT FOR A CONTROL LAW TO MAINTAIN A SET POINT VALUE.

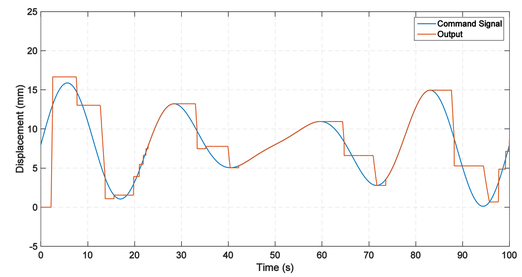
SOLUTION

3 SPECIES MODEL

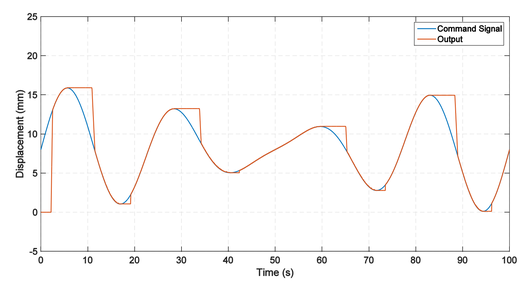


FOR ANY PARTIAL OR COMPLEX THERMOMECHANICAL PATH THE CURVE ALWAYS RETURNS TO THE PRIMARY MAJOR HYSTERESIS LOOP

CONTROL IMPLEMENTATION



ON-OFF CONTROL RESPONSE WITH BRINSON'S MODEL



ON-OFF CONTROL RESPONSE WITH 3 SPECIES MODEL

CONCLUSION

BRINSON'S PHENOMENOLOGICAL MODEL → INCORRECT RESPONSES FOR COMPLEX THERMOMECHANICAL PATHS (OVERSHOOT & RATCHETING)

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INCREASES BURDEN ON CONTROL ALGORITHM

← SOLUTION

THREE SPECIES MODEL

REFERENCES

[1] Madill, D., Wang, D., "Modeling and L_2-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).