RESEARCH TOPIC FOR THE PARISTECH/CSC PHD PROGRAM

Field: Materials Science, Mechanics, Fluids

Subfield: Mechanics of Materials, Phase Field Fracture, Shape Memory Alloys

Title: **Phase field fracture modelling of shape memory alloy actuators for aerospace applications**

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Framework: Scientific collaboration with Prof. T. Baxevanis, University of Houston (USA)

Short description of possible research topics for a PhD:

Within the last decades, Shape Memory Alloys (SMAs) have demonstrated a great potential in various engineering applications in aerospace. Indeed, SMAs are particularly attractive in a wide range of actuator, energy absorption, and vibration damping devices. This is achieved thanks to their unique thermo-mechanical behaviour which results from a crystallographic phase transformation from austenite to martensite and vice-versa. In our research group several phenomenological and micromechanical models have been proposed to describe the thermomechanical response of SMAs but none of them integrate their strain localization effects and the related crack initiation and propagation.

The present work aims at formulating a model accounting for stress-induced phase transformation integrating the martensitic reorientation mechanism in conjunction with forward and reverse austenite-martensite transformation. This model will be next associated with the phase field fracture modelling framework, which has recently proven to be particularly attractive to handle fracture problems with inelastic constitutive models, like the ones traditionally employed for SMAs. The phase field fracture method is based on the variational approach to fracture, which aims at seeking both the displacement field and the crack surfaces while minimizing the potential energy of the system. Thus, by approximating the discrete topology of cracks by means of a spatially regularized scalar damage-like variable (so-called crack phase field), the problem is reduced to a set two strongly coupled partial differential equations, which is far more efficient than classical discontinuous methods. Initially developed for elastic brittle materials, the phase field fracture method has a great potential and will be extended to inelastic SMAs exhibiting phase transformations mechanisms.

Required background of the student:

Mechanical engineering, Mechanical behaviour of materials, Finite element method

A list of 5 (max.) representative publications of the group:

1. G. Chatzigeorgiou, Y. Chemisky, and F. Meraghni, "Computational micro to macro transitions for shape memory alloy composites using periodic homogenization," Smart Mater. Struct., vol. 24, 2015.
2. F. Meraghni, Y. Chemisky, B. Piotrowski, R. Echchorfi, N. Bourgeois, and E. Patoor, "Parameter identification of a thermodynamic model for superelastic shape memory alloys using analytical calculation of the sensitivity matrix," Eur. J. Mech. - A/Solids, vol. 45, pp. 226–237, 2014.
3. D. Chatziathanasiou, Y. Chemisky, G. Chatzigeorgiou, and F. Meraghni, "Modeling of coupled phase transformation and reorientation in shape memory alloys under non-proportional thermomechanical loading," Int. J. Plast., vol. 82, pp. 192–224, 2016.
4. Y. Chemisky, D.-J. Hartl, and F. Meraghni, "Three-dimensional constitutive model for structural and functional fatigue of shape memory alloy actuators," Int. J. Fatigue, vol. 112, pp. 263–278, 2018
5. D. Chatziathanasiou, Y. Chemisky, F. Meraghni, G. Chatzigeorgiou, and E. Patoor, "Phase Transformation of Anisotropic Shape Memory Alloys: Theory and Validation in Superelasticity," Shape Mem. Superelasticity, vol. 1, no. 3, pp. 359–374, 2015.