Shape Memory Effects in Polymer Composites by Temperature Control Through Electromagnetic Induction Heating by Employing a Weakly Coupled Multi-Physics Multi-Timescale Model

Vinayak Gholap [1], Ludovic Noels [1], and Christophe Geuzaine [2]
[1] A&M department, University of Liege, Belgium
E-mail: vinayak.gholap@uliege.be
[2] Montefiore Institute, University of Liege, Belgium

Shape memory behavior refers to the ability of the material to shift from a temporary configuration to the permanent/original configuration under the influence of an external stimulus, such as temperature, electromagnetism, and light. Triggering the shape change in polymer composites through contactless temperature control induced through the losses incurred by the high frequency alternating electromagnetic fields is the primary focus of this work.

A multi-physics electro-magneto-thermo-mechanical (EM-TM) model employing mixed-FEM formulation with nodal and Nédélec's edge elements was developed for dynamic EM problems coupled with finite TM deformations. An efficient timescale coupling technique weakly coupling the respective multi-physics: the EM problem (at a timescale proportional to the high frequency of the electromagnetic source) and the TM problem, was developed and applied.

A finite strain phenomenological model for shape memory behavior of semi-crystalline polymers under thermo-mechanical loading was recently developed in-house (H. Gülaşik, M. P. Muñoz, and L. Noels, "A Thermo-Mechanical, Viscoelasto-plastic Model for Shape Memory Polymers", in preparation). The visco-elasto-plastic constitutive model for the thermo-mechanics of the shape memory polymer is extended considering: i) weak coupling with the dynamic EM problem by employing the multi-timescale coupling ii) the heat source arising from the losses incurred by the alternating EM fields. The developed weak coupling algorithm accounts for the large deformations in the polymer while computing the EM fields and the EM heat source by a) remeshing the geometry used in the EM problem by importing the deformed configuration from the TM problem b) transfer of the relevant fields with appropriate kinematic transformations between the deformed and the reference configuration.

Shape memory effects with shape fixity, shape recovery, and phase transition achieved by controlling the temperature in the polymer through EM sources will be demonstrated by numerical test results.