

Multiscale thermo-chemo-magneto-mechanical modeling of polycrystalline magnetic shape memory alloys

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Magnetic shape memory alloys (MSMA) are among the most promising alloys for designing miniature sensors or actuators. Besides stress and temperature dependence, a macroscopic deformation can be achieved by applying a magnetic field (due to some phase transition and/or some variants selection). The associated piezomagnetic effect in these materials can also be very high. On the other hand, the phase transition leads to strong heat exchanges. Due to the induced thermo-magnetic coupling, these materials are very interesting candidates to be part of a new generation of thermo-magnetic power generation devices [1].

These behaviors are strongly associated with transformations at the single crystal scale and with the magnetic domains re-organization. The development of micro-macro approaches is consequently relevant for the modeling especially when a polycrystalline medium is considered. In this paper, a multiphysics (fully coupled thermo-chemo-magneto-mechanical problem) and multiscale (magnetic domain, variant, grain and polycrystal) modeling of these materials in a multi-axial framework is presented. It uses a homogenization method and a free-energy dependent stochastic approach as a basis of a reversible constitutive law [2,3]. Hysteretic phenomena associated with nucleation/growth phenomena and with magnetization are next considered thanks to the calculation of an irreversible loading term. The macroscopic quantities at the polycrystalline scale are computed through averaging operations. Numerical results are compared to experimental results from literature illustrating the wide variety of phenomena induced by these couplings.

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[2] L. Daniel, et al., *JMPS*, 56 (2008) 1018-1042, DOI :10.1016/j.jmps.2007.06.003

[3] M.D.Fall, et al., *IEEE Trans mag*, 52, (2016) 1-4, DOI 10.1109/TMAG.2016.2514705