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Multiscale modelling of chemo-magneto-elastic couplings in Magnetic Shape Memory Alloys

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Classic Shape Memory Alloys (SMA) exhibit a coupled thermo-mechanical behavior. Increasing use of Shape Memory Alloys for complex applications requires a robust multiphysic modelling of phenomena governing their behavior taking account multiaxial mechanical loadings. The development of micro-macro approaches is relevant since the behaviour is strongly associated to transformations at the single crystal scale. Such approach relies the definition of transition scale rules, depending on the microstructure, and a description of the behaviour of constituents.
Magnetic shape memory alloys (MSMA) exhibit a more complex multiphysic coupling than classic SMA. Besides stress and temperature, a macroscopic deformation can be achieved by applying a magnetic field (due to a phase transition and/or a variants selection). MSMAs can be used as electromagnetic actuators in extremely large application domains, from largest to smallest scales.
In this paper, we give first the principles of a unified multiscale modelling of these materials using a homogenization method and a stochastic approach as a basis of the constitutive law [1,2,3]. Indeed the model is based on the comparison of the free energy of each variant and calculation of associated volume fractions thanks to a probabilistic approach at the single crystal scale. Averaging operations allow calculating the macroscopic quantities at the polycrystalline scale.
The modelling is applied to the prevision of a specific Ni_2MnGa MSMA behaviour. Numerical results are compared to experimental results from literature and others obtained in the laboratory illustrating the wide variety of phenomena associated with magneto-mechanical and chemo-mechanical couplings.

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