1 INTRODUCTION

Reference configuration Deformed configuration

Polycrystal

Composite

2 MICROMAGNETIC-ELASTIC MODEL

Ω material domain p phase index θ lattice orientation

Elasticity,

\[ E_{\text{elas}} = \frac{1}{2} \int_\Omega W_{\text{MSSM}}(V(x), M(x)) \, dx \]

\[ \varepsilon_1 = \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}, \quad \varepsilon_2 = \begin{pmatrix} 0 & 0 \\ 0 & -\varepsilon_0 \end{pmatrix} \]

eigenstrains

\[ E_{\text{elas}} = \frac{1}{2} \int_\Omega W_{\text{poly}}(V(x)) \, dx \]

\[ \phi_{m}(m) = m_1^2, \quad \phi_{\psi}(m) = m_2^2 \]

\( m \) magnetization \( H_a \) stray field \( R_F \) rotational part of \( F \)

3 SIMULATION RESULTS

Experiment by O. Gutfleisch et al.

4 RELAXATION

Microstructure of twins and magnetic domains significantly smaller than particle/ grain geometry: Compute only volume fraction of twin variants and average magnetization

\[ \gamma(p, m) = \begin{cases} m_1 & p = 0 \\ m_2 & p = 1 \end{cases} \]

Then its convex envelope for \( |m| \leq 1 \) and \( p \in \{0, 1\} \) is

\[ \gamma^{\star}(p, m) = \frac{m_0 \iota}{p \iota} \iota, \]

5 RATE-INDEPENDENT EVOLUTION

Toy model.

Slow external forcing, energy completely dissipated:

\[ \varepsilon(s(t)) + D(s(0), x(t)) = \varepsilon(0, x(0)) + \int_0^t \partial\varepsilon(x(s)) \, ds \]

Implicit time discretization for \( t = 0, \tau, 2\tau, 3\tau, \ldots \):

\[ x(t) \text{ is minimizer of } \varepsilon(t, x(t)) + D(s(t - \tau), x(t)) \]

Simulation: preliminary numerics

To Do:

- Inclusion of particle elasticity, magnetization modulation, and appropriate boundary conditions in the current simulation algorithm
- Polycrystals
- Large grain limit of the evolutionary model combining relaxation and hysteresis
- Systematic simulations: geometric criteria for continuous switching (with project B9, H. Janocha and B8, O. Gutfleisch)

6 COOPERATIONS & CONNECTIONS

Project B8 Polymer bonded textured composites with single crystalline Ni_{50}MnGa particles for magnetic-field controlled dampers and actuators (O. Gutfleisch).
- modeling based on experimental observations
- improvement of material production based on theory
- identification of length scales for relaxation approach
- effect of composite geometry on twin boundary motion

Project A7 Continuum models of magnetic shape memory materials: mathematics (S. Müller, F. Otto).
- phase transitions at different time and length scales
- mathematical techniques for microstructured materials

Project B9 Magnetic Shape-memory alloys as active materials for vibration damping (H. Janocha).
- design of composites with homogeneous switching

Project A5 Phase-field modelling of magnetically induced microstructure evolution in martensitic polycrystals (B. Nesterl).
- phase field models for martensitic microstructures

A6: Mathematical Modeling and Simulation of Microstructured Magnetic-Shape-Memory Materials

Sergio Conti, Martin Lenz, and Martin Rumpf

Institute for Applied Mathematics and Institute for Numerical Simulation
Bonn University