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Dipartimento di Meccanica Strutturale - Università di Pavia

in collaboration with

Istituto di Matematica Applicata e Tecnologie Informatiche - IMATI (CNR)

An analytical study on the stress-induced variant reorientation in a slender NiMnGa sample

NiMnGa alloys are a group of fascinating materials which can undergo a significant and reversible strain (6-10%) driven by the external force or magnetic field. These materials are also called magnetic shape memory alloys (MSMAs). The underlying mechanism responsible for this unusual property is the stress- or magnetic field-induced reorientation of the martensite variants.

Systematic experiments have been conducted on the mechanical responses of a single-crystalline NiMnGa sample subject to the uniaxial compression (or tension) and some interesting features have been observed. For example, the variant reorientation process is always realized by the nucleation and propagation of the twin interfaces. Correspondingly, the measured engineering stress-strain curves have a nucleation stress peak and a stress plateau. It was also found that the twin interfaces form a fixed angle with the loading axis and the sample is deflected during the variant reorientation process.

In this work, a constitutive model is proposed to study the stress-induced variant reorientation in a 2D NiMnGa sample. An internal variable, called variant state variable, is adopted to describe the variant reorientation process. The governing system is composed of the mechanical field equations and the evolution laws for the variant state variable. The natural configurations corresponding to the different variant state values are proposed, based on which the total strain is decomposed into the transformation strain and the elastic strain. The coupled series-asymptotic expansion method is then applied to reduce the governing system into a simple ODE system, which is valid in an asymptotic sense. The coefficients of this ODE system depends directly on the material constants. By conducting a phase plane analysis, the explicit solutions to the asymptotic ODE system is constructed. It is found that the analytical results obtained can capture most of the experimental features (e.g., the nucleation and propagation of the twin interfaces, the key features of the stress-strain curves and so on).

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