Kinetics of Materials with Wiggly Energies: Theory and Application to the Evolution of Twinning Microstructures in a Cu-Al-Ni Shape Memory Alloy

R. Abeyaratne
Department of Mechanical Engineering
Massachusetts Institute of Technology
Cambridge, Massachusetts

C. Chu and R.D. James
Department of Aerospace Engineering and Mechanics
University of Minnesota
Minneapolis, Minnesota

September 26, 1995

Abstract

We analyze the kinetics of the transition between two variants of martensite during biaxial dead loading. The volume fraction of one martensite variant vs. the applied loads exhibits an unusual hysteresis, characterized by a sensitive dependence on the amplitude of the loads and a dissipationless response at small amplitude. Observation of the microscopic volume fraction at the level of a few bands of martensite reveals that the main mechanism by which one variant grows at the expense of another is a tip-splitting event: the tips of martensite needles present in the specimen suddenly split. This leads us to adopt a form of the energy in which many little wiggles are superposed on a slowly varying function that accounts for the loading device, elastic and interfacial energies. We analyze the resulting microscopic kinetic law by deriving from it a macroscopic kinetic equation that governs the average response. This law inherits the phenomenon of "getting stuck in local minima of the energy." It leads to good qualitative (and fair quantitative) agreement with observation over a very wide range of different kinds of experiments.