Friedrich-Alexander-Universität Erlangen-Nürnberg

Seminar über Fragen der Mechanik

zu folgendem Vortrag wird herzlich eingeladen

Dienstag, 21.12.2010, 16:00 Uhr, Egerlandstr. 5, Raum 0.044

An analytical study on stress-induced phase transitions in a slender SMA layer

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Shape memory alloys (SMAs) are a group of fascinating materials which can undergo a dimensionless transformation between two solid phases, called austenite and martensite. This transformation endues SMAs with two remarkable properties: the shape memory effect and pseudoelasticity. Due to the unique characteristics and widely applications, SMAs have been extensively studied, both experimentally and theoretically, over the past several decades.

Some interesting experimental features have been observed in the systematic uniaxial tension experiments on slender SMA structures (wires, strips, tubes, etc). For example, the phase transition process was realized by the nucleation of the product phase band, the propagation of the phase fronts along the specimen and the coalescence of the phase fronts. Correspondingly, the measured engineering stress-strain curves have some key features, e.g. the nucleation stress peak (for the loading case) and stress valley (for the unloading case), the stress plateaus, the rate-independent hysteresis loop and so on.

In this work, an internal-variable rod model is proposed to study the stress-induced phase transitions in a 2-D SMA layer. To fully model the mechanical responses of SMAs at a continuum level, we introduce two independent energy functions: the Helmholtz free energy and the rate of mechanical dissipation. An internal variable, called the phase state variable, is adopted to describe the phase transition process. Starting from the 2-D governing system and by using the coupled series-asymptotic expansion method, one single equilibrium equation is derived, which involves the leading order term of the axial strain and the phase state functions. Further by using the phase transition criteria, we derive the asymptotic evolution laws of the phase state functions for the purely loading and purely unloading processes. As a result, the governing ODEs corresponding to the outer-loop of the stress-strain curves are obtained, which are called the asymptotic rod equations. By conducting a phase plane analysis, we construct the explicit solutions to the asymptotic rod equations. It is found that the analytical results obtained can capture most of the experimental features. Especially, the instability phenomena observed in the experiments can be interpreted as a jump of the state of SMA layer from one metastable solution to another more preferred solution. Some further analysis has also been conducted on the inner-loops of the stress-strain curves.

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