On the thermomechanical aspects of martensitic phase transformation in nano-indentation of pseudoelastic shape memory alloys

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ABSTRACT

Pseudoelasticity is one of the key features of shape memory alloys (SMAs). It refers to the ability of the material to recover large deformations upon unloading. When a macroscopic pseudoelastic SMA specimen is subjected to external mechanical loads at high rates, thermomechanical interactions that result from the latent heat of transformation lead to a complex transformation pattern and mechanical response, see e.g., [1]. It can be intuitively conjectured that at the micro/nano-scale, the thermomechanical interactions are less severe than at the macro-scale due to the dominant role of heat conduction. A handful of nano-indentation experiments on NiTi SMAs have addressed the thermomechanical interactions by investigating the effect of the indentation loading rate on the material's behavior [2,3,4]. Notably, significant rate effects have been captured in the experiment done by Amini et al. [2,3] and this has led to some ambiguities regarding the importance of thermomechanical interactions in SMAs at such small scales. The present study aims to clarify these ambiguities. For this purpose, the maximum heat rise during an adiabatic phase transformation is first calculated from the heat equation. A simple model of pseudoelasticity is then employed and the corresponding material response is calibrated so as to describe the thermally-hardened material response in adiabatic condition. The calibrated material response is then used to model the indentation-induced phase transformation in NiTi and the obtained results, which represent the upper-bound of thermomechanical coupling effects, are compared with the corresponding isothermal case.

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