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Modelling the Thermomechanical Response of Metastable Beta-Titanium Shape Memory Alloys

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Extended Abstract

Abstract

Over the last two decades, new nickel-free shape memory alloys (SMAs) based on metastable titanium alloys have been discovered. To exploit their potential in biomedical or other applications, a reliable and effective computational tool is needed. Although constitutive models of various SMA families (e.g. Cu-based or Fe-based) can be found in the literature, those for NiTi and NiTi-based SMA remain by far the most elaborated ones. Indeed, the strongly coupled influence of stress and temperature on the martensitic transformation, the easy reorientation and mechanical stabilization, tension-compression asymmetry – these and many other phenomena were successfully captured. However, the transferability to the metastable titanium alloys remains to be explored. The present work reports the first attempts in this direction, and introduces a finite-strain model for a stabilized superelastic metastable beta-Ti alloy with the nominal composition Ti–18Zr–11Nb–3Sn (at.%), hereinafter denoted as TiZrNbSn. Our original small-strain constitutive model for the reversible mechanical behaviour of NiTi SMA was modified to capture the stable response of the TiZrNbSn alloy. The free energy function was refined to reflect the particular morphology of

hysteresis loops. Experimental data were used to fit the superelastic reaction at room temperature. The logarithmic strain space approach was employed to reliably simulate evolutionary problems, including large rotations and/or finite strains. The model was implemented using the finite element method with in-house developed MATLAB code, heavily employing vectorization techniques. After fitting to experimental data, computational simulations of boundary-value problems were conducted for TiZrNbSn and NiTi alloys for validation and comparison purposes.

Keywords:

beta-titanium alloys martensitic transformation superelasticity constitutive modeling