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NUMERICAL AND EXPERIMENTAL INVESTIGATION OF SHAPE MEMORY ALLOYS SUBJECT TO COMPLEX MECHANICAL LOADING: A CASE STUDY OF A NITI HELICAL SPRING

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Summary: Shape memory alloys (SMA) are metallic materials exhibiting unusual properties of being able to sustain and recover large strains (superelasticity) and to "remember" the initial configuration and return to it with temperature change (one-way shape memory effect). These properties make them very suitable for utilization as actuators. One of the simplest possible geometry in terms of manufacturing and utilization is the form of a helical spring. For its optimal design and control detailed information on evolution of internal state of the material during operation is advantageous. In this work a macroscopic constitutive model tailored for NiTi shape memory alloys exhibiting R-phase transition, transformation strain anisotropy and tension-compression asymmetry is employed. It features an elaborated, asymmetric form of the rate independent dissipation function coupling martensitic transformation and reorientation processes, whose specific form was inspired by experimental observations. Numerical simulations of mechanical loading of the spring at various temperatures compared with macroscopic experimental data confirm good predictive capability of the model. Because of naturally non-proportional loading mode combining bending and torsion, distributions of stress components within cross-section of the wire predicted by the model are quite complex. They allow to identify potential loci of initiation of irreversible deformation for this type of loading.