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Electric resistance variation of NiTi shape memory alloy wires in thermomechanical tests: Experiments and simulation

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Abstract

Evolution of the electrical resistivity during thermal and mechanical tests of NiTi wires showing R-phase transformation was investigated by experiments and micromechanical model simulations considering B2-R-B19′ transformations. Since reasonable agreement between the simulated and experimental mechanical and electrical resistivity responses was achieved, the apparently curious behavior of electrical resistivity could be rationalized through the model simulations in terms of the activity of multiple transformation and deformation processes taking place in the activated NiTi wires.

Keywords: NiTi; Wires; Electric resistance; Thermomechanical tests

1. Introduction

Electrical resistivity variations of shape memory alloys (SMAs) during thermal or mechanical tests have been investigated for a long time [1–11]. Variations were traditionally considered to depend mainly on the volume fractions of the austenite and martensite phases in the sample and, in addition to this, on the texture in the product martensite phases. Measurements of the variation of electric resistance of SMAs with temperature have commonly been used to evaluate transformation temperatures of SMAs [1]. Analogically, the electric resistance of SMAs was evaluated during mechanical tests or even thermomechanical tests to detect the onset and end of the stress induced martensitic transformation or even reorientation processes [2]. However, the results, particularly those recorded under thermomechanical loads, are often very difficult to understand and interpret. For example, quite complicated electrical resistivity responses in thermomechanical tensile tests were reported [5,11] for NiTi wires focused in this work. Slightly different alloys (e.g. NiTi with Fe or Cu additions) may exhibit quite different behaviors [7,12] of electric resistance.

There were also numerous attempts in the literature to use the electrical resistance of NiTi wire as a feedback for strain in actuator applications [3], taking advantage of the observed linear dependence of the electrical resistance on strain. Nevertheless, in spite of many years of electrical resistance studies on NiTi wires, we have to admit that the complex electric resistance behaviour during thermomechanical loads are not yet generally understood. The electric resistance still cannot be safely used as a feedback signal in actuator applications.

One of the reasons for this seems to be the appearance of the rhombohedral R-phase in NiTi wires, which has significantly higher electric resistance compared to the B2 austenite and B19′ martensite phases. If there is no R-phase (e.g. in fully annealed NiTi wires), electrical resistivity responses are relatively simple. The problem is that the R-phase in superelastic NiTi wires appears not only during cooling/heating cycles, as clearly evidenced by the differential scanning calorimetry (DSC) experiments, but generally in any thermomechanical tests [13] under suitable stress–stain–temperature conditions. Detection and recognition of deformation/transformation processes involving R-phase in thermomechanically loaded NiTi wires is also possible. In situ neutron diffraction, electrical resistivity and ultrasonic evaluation of elastic properties [13] were recently proposed as suitable methods for that.

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