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UNIFORM OR LOCALIZED PURE BENDING DEFORMATION OF SUPERELASTIC NiTi THIN WIRES

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Summary Most medical applications involving superelastic Ni-Ti shape memory alloys are based on thin wires or tubes. If the tensile behavior of such specimens has been extensively described in the literature, only few studies deal with their mechanical behavior under pure bending and compressive load [1]. In this paper, Ni-Ti wire behaviors were experimentally investigated using pure bending and uni-axial tensile experiments. Uniform or localized behaviors were observed depending on the thermo-mechanical treatment of the wire. Theoretical bending model was proposed. For nonlocalized tests, it allowed to analyze tension-compression asymmetry. Tension and compression constitutive equations were proposed to model localization in bending.

INTRODUCTION

This paper aims at identifying the influence of thermo-mechanical treatment on Ni-Ti thin wires behavior under tensile, compressive and pure bending load. Uni-axial tensile and pure bending tests were performed on Ti 50.8%atNi wires of diameter 0.5 mm supplied by Fort Wayne Metals in their cold worked conditions. Three different thermomechanical treatments were realized 200 °C for 30 min, 250 °C for 30 min and 500 °C for 60 min.

TENSION AND PURE BENDING EXPERIMENTS

Uni-axial tensile tests were performed in nearly isothermal conditions using a Gabo EPLEXOR 500N machine. Tensile nominal stress strain curves are plotted in Fig. 1, (a). A localization phenomenon has been observed for the 500 °C wire.

Pure bending experiments were performed using a home-made device [2]. Curvatures were estimated using pictures taken during the test and synchronized with the bending moment measurement. Global curvature was estimated by fitting an arc of circle on the deformed wire of length 10 mm. Bending moment-global curvature curves are plotted in Fig. 1, (b).

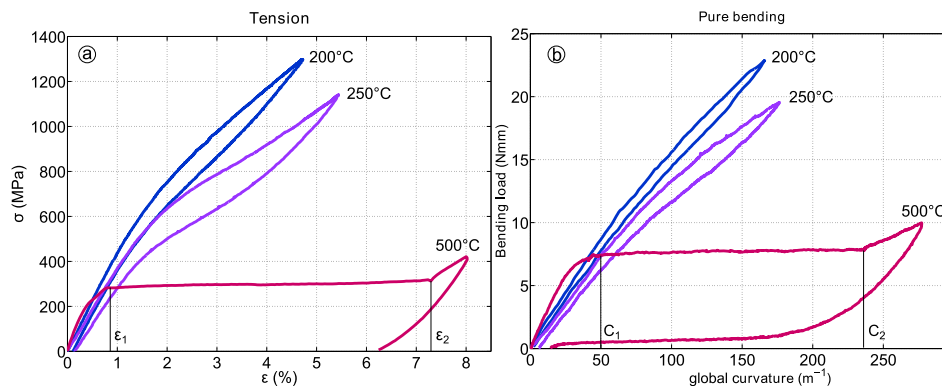


Figure 1: Experimental thin NiTi wire behaviors: (a) under tensile stress, (b) under pure bending load.

The local curvatures of the samples along their curvilinear abscissa s were also identified during the pure bending experiments. For the 200 °C (not shown here) and 250 °C wires, the local curvature remained uniform along the sample during the whole experiment (Fig. 2, (a)). In contrast, local curvature along the 500 °C wire was found to be highly non-uniform, suggesting localization occurred during the test (Fig. 2, (b)).

MODELLING

A bending model was proposed assuming Navier-Bernoullis hypothesis, i.e. that a plane section of the wire normal to its longitudinal axis prior to loading remains plane and normal to the deformed neutral axis after the loading. Using Digital Image Correlation measurement, this hypothesis has been experimentally verified for wires [3]. This model allows to estimate

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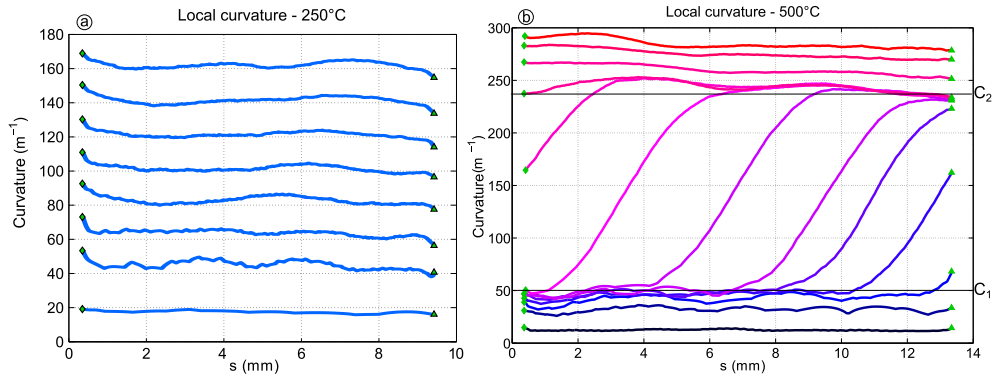


Figure 2: Local curvature during pure bending test along initial curvilinear abscissa s : (a) thin NiTi wire treated at 250 °C, (b) thin NiTi wire treated at 500 °C, a localization phenomena can be noticed.

the moment as function of the curvature and the position of the neutral fiber as function of the constitutive equations in tension and compression.

For wires treated at 200 °C and 250 °C, axial strain (resp. local curvature) is uniform during tension tests (resp. bending tests). Tension and bending results were combined to determine wires compressive behavior during the first loading. The obtained compression stress-strain curves are plotted in Fig. 3, (a). Asymmetric tension-compression behavior is well observed [4].

For the wire treated at 500 °C, using the compressive constitutive equation represented Fig. 3, (b), green full line, and the experimental tensile curve as the constitutive equation in tension, the model predicts the curve presented Fig. 3, (b) black dashed line. This result is inconsistent with a localization phenomenon in bending. If the curve shown Fig. 3, (b) red full line, is adopted as the constitutive equation in tension [5], the predicted bending behavior (Fig. 3, (c) black full line) is compatible with the localization experimentally observed (Fig. 2, (b)).

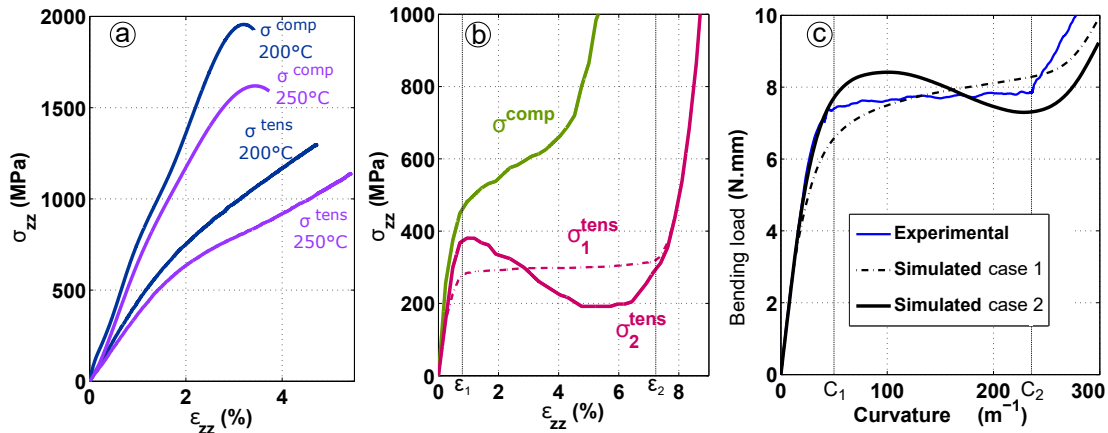


Figure 3: Result of the modelisation: (a) for wires 200 °C and 250 °C, (b) for wire 500 °C, (c) corresponding bending moment for wire 500 °C.

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