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Temperature visualisation of shape memory alloy various behavior

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Abstract

Temperature effects related to stress-induced martensite transformation developing in TiNi shape memory alloy have been presented. The specimens have been subjected to deformation tests carried out below, at and above the SMA A_f temperature. Exothermic martensite forward and endothermic reverse transformations have been recorded with use of an infrared camera. It was found that the temperature distribution was uniform during straining below the A_f while investigating so called shape memory effect, whereas bands of significantly higher temperature corresponding to the localized *Lüders*-like martensitic transformation were recorded during the deformation process carried out above the A_f temperature.

1. Introduction

The shape memory effect (SME) and superelasticity (SE) are the main characteristics which appear in a shape memory alloy (SMA), depending on the test temperature *T*, in respect to the material austenite finish temperature A_f [1-2]. If *T* is higher than A_f, the SE appears. If *T* is lower than A_s (austenite start), the SME appears. In the case of the SME, if the specimen is heated after unloading, the residual strain and martensitic phase (M-phase) disappears. The recoverable strain of the SMA is quite large compared to the normal metals. The recovery stress of the SMA is very large and can be used as the driving force of actuators and heat engines. The energy storage and dissipation due to the SE are also very large. The SMAs has these unique properties, and therefore their development and application are expected as the smart materials and structures [3]. The MT is induced by variation in temperature or stress, and the deformation behavior due to the MT depends on the thermomechanical loading condition. In order to design the SMA elements properly, it is important to understand the influence of the thermomechanical loading conditions on the progress of the MT and the corresponding deformation behavior [4-5]. Mechanism of the phase transformation, its nucleation, development as well as the question how far the process is homogeneous, are the subject of some recent studies, since the homogeneity usually assures higher material variability [4].

2. Results

The mechanical and the temperature characteristics obtained during loading and unloading TiNi SMA specimens at the temperature below, at and above the SMA Austenite finish temperature (A_f) are presented in Figures 1-3, respectively.

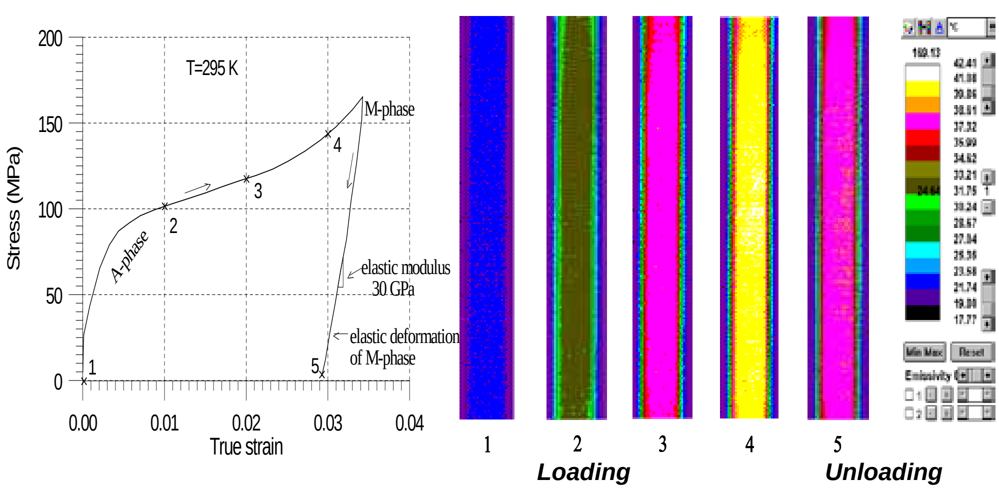

Fig. 1. *Stress-strain curve and temperature distribution on the surface of TiNi SMA tape obtained at various strains under strain rate of 1.87×10^{-3} s^{-1} during loading and unloading at $T<A_f$ observed by the infrared thermography*

One can find from Fig. 1 that the temperature increases during the SMA loading and decreases during the unloading process. The temperature distribution for the deformation process performed at $T< A_f$ is uniform, manifesting that the transformation carried out in homogeneous way.

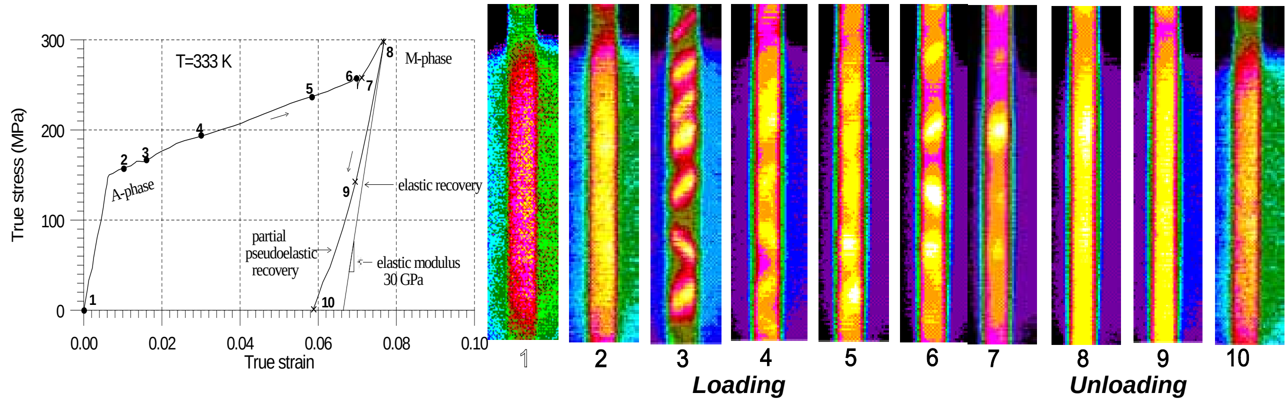

Fig. 2. *Stress-strain curve and temperature distribution on the surface of TiNi SMA tape at various strains under a strain rate of 1.87×10^{-3} s^{-1} during loading and unloading at $T=A_f$ observed by the infrared thermography*

Looking at Fig. 2 one can notice that the temperature distribution of the SMA subjected to loading at $T=A_f$ is not uniform, especially during the loading process, manifesting that the martensite transformation is not homogeneous.

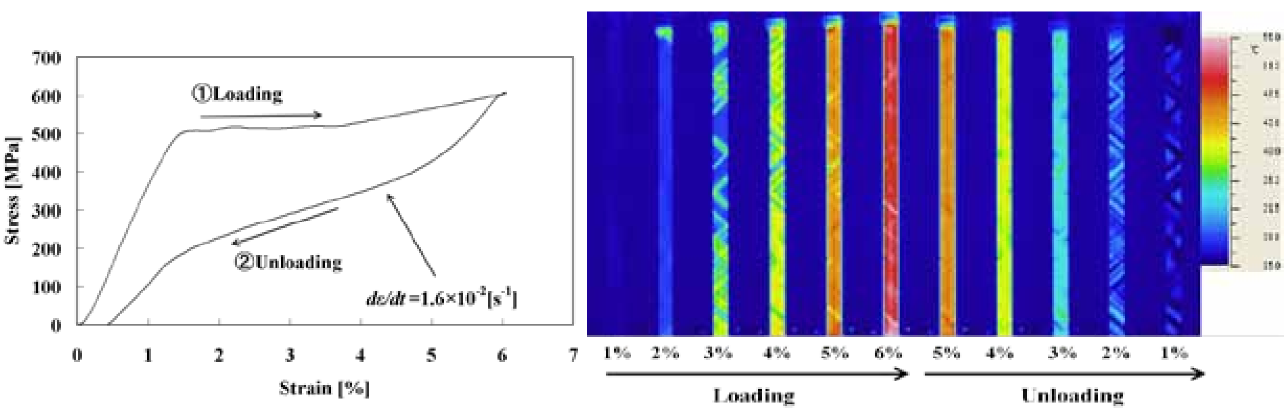

Fig. 3. *Stress-strain curve and temperature distribution on the surface of a TiNi SMA tape at various strains under a strain rate of 1.6×10^{-2} s^{-1} during loading and unloading at $T>A_f$ observed by the infrared thermography*

Looking at Fig. 3 one can observe a localized *Lüders*-like deformation, recorded for the tension test carried out above the A_f temperature. Bands of significantly higher temperature, corresponding to the localized inhomogeneous martensitic forward transformation were recorded during the SMA loading, whereas bands of significantly lower temperature, corresponding to the localized reverse transformation were recorded during the SMA unloading process, respectively.

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