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Development of stress-induced martensitic transformation in TiNi Shape Memory Alloy

Elzbieta Alicja Pieczyska
Institute of Fundamental Technological Research PAS, Warsaw, Poland
epiecz@ippt.gov.pl

Hisaaki Tobushi
Aichi Institute of Technology, Toyota, Japan
tobushi@aitech.ac.jp

Introduction

A development manner of the stress-induced martensitic transformation (SIMT) associated with the unique properties of shape memory alloys (SMA) and their applications have been recently studied in several research centers [1]. It is well known that the SIMT forward is exothermic whilst the reverse one exhibits endothermic property. The temperature changes were estimated for simple shear [2], tension [3], and compression [4]. In this research, we focus on three SIMT aspects: the nucleation of the initial macroscopically homogenous transformation, the initiation and development of the localized bands, and the conditions of the transformation saturation.

Experimental Results and Discussion

Belt type specimens were subjected to tension performed at various strain rates. Mechanical characteristics, infrared imaging and temperature changes accompanying the TiNi pseudoelastic behavior were working out using fast (538 Hz) and sensitive (0.025 K) infrared camera. The stress and the mean temperature changes obtained for the strain rate $10^{-3}s^{-1}$ are shown in Fig. 1. The initial, elastic range of the loading is followed by the next pseudoelastic stage, associated with intense transformation and huge temperature increase. It is worth noting that the average temperature of the SMA specimen starts to increase even before the stress-strain knee, at approximately 400 MPa, manifesting the onset of the SIMT at this stage. The advanced transformation, developing in the bands, is associated with a huge heat production and the significant temperature increase, over 20 K in case of the strain rate applied (Fig. 1, Fig. 2).

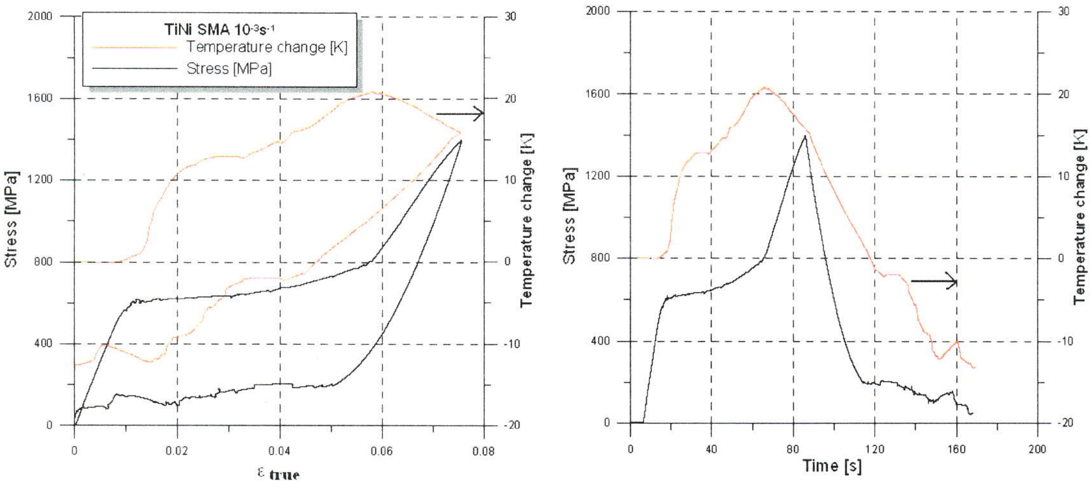

Figure 1. Stress and temperature change vs. strain (left) and vs. time (right) obtained during TiNi tension at 10^{-3} s^{-1}

Thermograms in Fig. 2 show in infrared a nucleation and evolution of macroscopic transformation bands, related to martensite forward (2-10) and reverse (11-19) transformation. Before the tension was started, the temperature of the specimen was uniform and equal to the ambient temperature (Fig. 2: 1st thermogram). At the certain level of the stress and strain state, the temperature starts to grow slowly, however its thermal image remains uniform, indicating the homogeneous nature of the initial transformation process (2d thermogram). At higher strains, inclined bands of significantly higher temperature (≈ 8 K) are observed, starting in the specimen grip areas and developing towards the specimen center (thermograms 3-7). They were called transformation bands or Luders-like deformation [3].

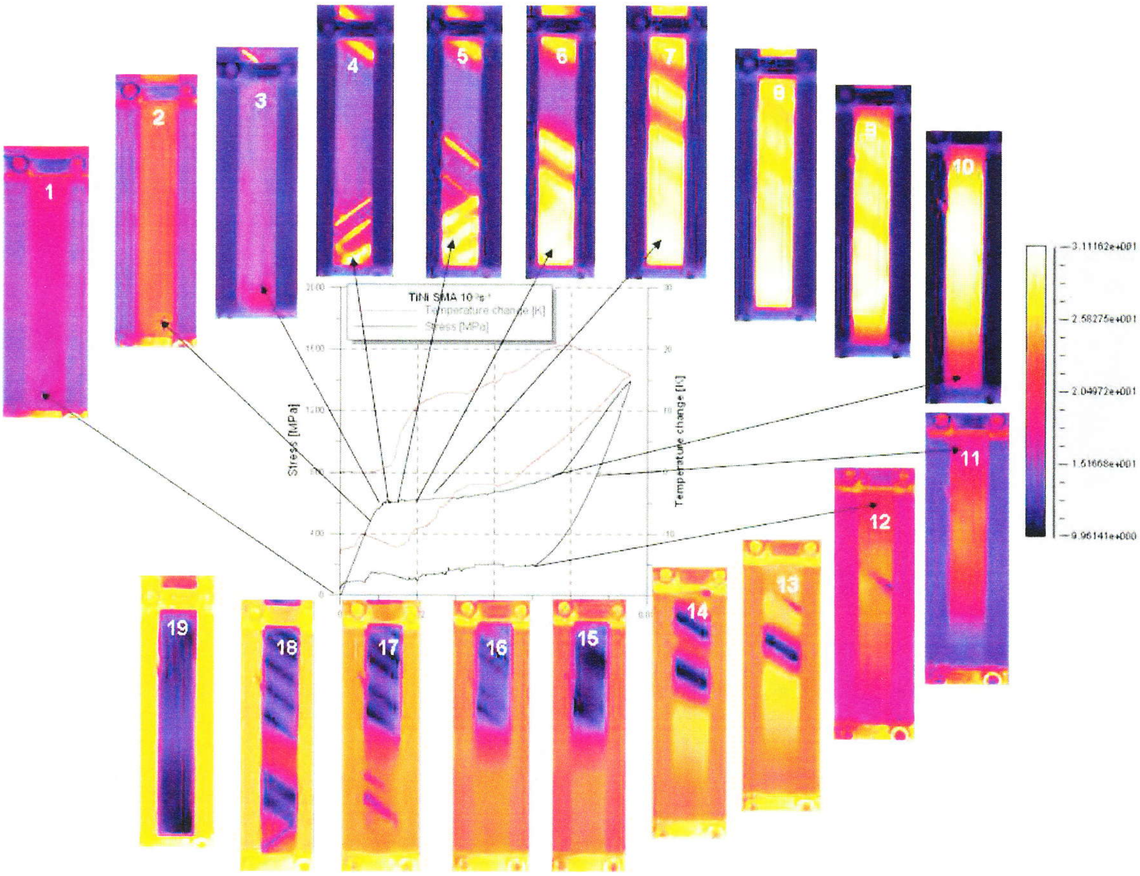

Figure 2. Stress and temperature changes vs. strain curves obtained during TiNi SMA tension at strain rate $10^{-3}s^{-1}$.

In the course of the SMA unloading, the specimen temperature decreases significantly (Figs 1, 2) and bands of lower temperature, inclined by the similar slope, are developing (thermograms 12-18). It was observed for the all strain rates applied that the bands of reverse transformation always nucleate from central part of the specimen [5].

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