Proceedings

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INVESTIGATION OF SHAPE MEMORY MATERIALS CONDUCTED IN IPPT PAN (POLAND) IN COOPERATION WITH JAPAN (1990-2016)

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1. Investigation on shape memory alloys

Research on shape memory alloys (SMA) has been developed in the Institute of Fundamental Technological Research of the Polish Academy of Sciences (IPPT PAN) since the beginning of 90-ties of the 20th century. B. Raniecki in cooperation with K. Tanaka (Japan) and C. Lexcellent (France) proposed advanced thermodynamic models whereas H. Petryk and S. Stupkiewicz analysed the micromechanics, related to the SMA structure evolution. In order to obtain data necessary to verification of the proposed models, various experiments, coordinated by L. Dietrich and W.K. Nowacki were conducted in IPPT in collaboration with Japanese researchers: S. Miyazaki, University of Tsukuba and H. Tobushi, Aichi Institute of Technology. E.A. Pieczyska and S.P. Gadaj completed the mechanical data by the additional experimental results. The temperature changes accompanying the SMA loading and reflecting the martensite transformation progress were monitored by infrared thermography. Using a fast (538 Hz) and sensitive (0.025 K) infrared camera, it was confirmed that the stress-induced martensite forward transformation (SIMT) is exothermic whereas the reverse is endothermic. The results were modeled by V. Dunic, University of Kragujevac [1]. An example of the stress and average temperature change vs. strain curves obtained during the TiNi SMA complete loading-unloading tension cycle accompanied by an infrared imaging is presented in Fig.1. It was found that the initial, macroscopically homogeneous transformation initiates before the knee of the stress-strain curve, subsequently, localized SIMT is observed. An inflection point (I) was noticed on the stress-strain curve, dividing the transformation range in two stages: the first macroscopically heterogeneous, when the bands nucleate and evolve throughout the specimen; the second, where the bands overlap causing significant temperature and stress increase. Thermograms show: (2) initial uniform transformation, (3-7) macroscopic bands related to exothermic forward, whereas (8-12) endothermic reverse transformation [2, 3].

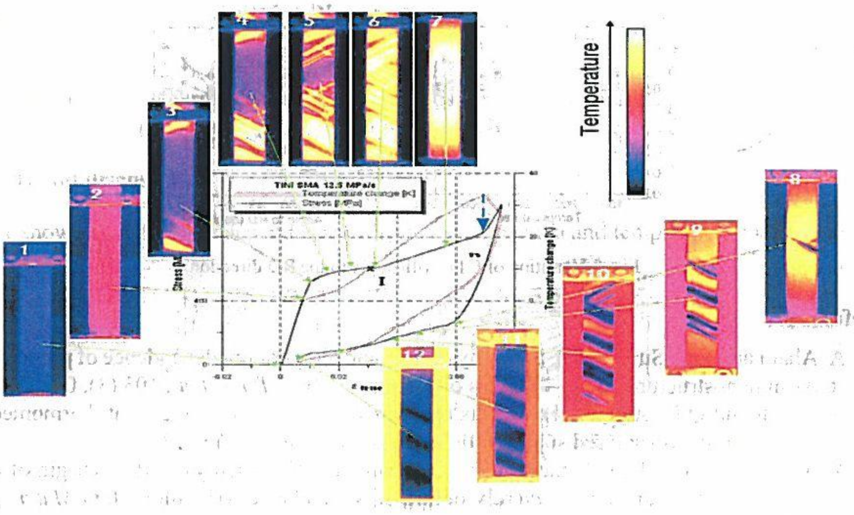

Fig. 1. Stress and temperature change vs. strain curves obtained during SMA tension at 12.5 MPa/s.

2. Investigation on shape memory polymers

Experimental and numerical investigation of shape memory polymers (SMP) has been carried out in IPPT PAN since 2005 in cooperation with H. Tobushi and S. Hayashi. An example of the stress and temperature changes vs. strain curves obtained for SMP (T_g=45°C) during tension at strain rate of $10^0 s^{-1}$ within strain range 0.81 is presented in Fig. 2 [4]. Below the diagram, thermograms (1-6) present subsequent stages of the SMP deformation process; (1) shows the image of a specimen before its loading, (2) depicts the temperature decrease due to the thermoelastic effect, whereas thermograms (3-6) present nucleation and evolution of the strain localization. A thermogram (7) presents SMP when unloaded and a corresponding photograph (7') of the specimen shows the strain localization.

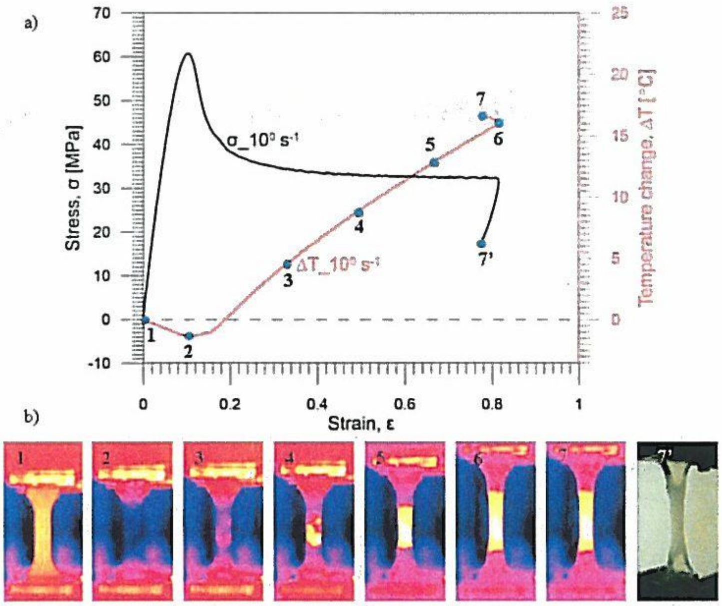

Fig. 2. SMP subjected to tension: a) σ and ΔT vs. ε; b) subsequent thermograms [4].

Acknowledgments

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3. References

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