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FERROMAGNETIC SINGLE CRYSTAL SHAPE MEMORY ALLOY SUBJECTED TO SUBSEQUENT COMPRESSION CYCLES

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1. Introduction

The paper presents effects of thermomechanical coupling related to pseudoelastic deformation of NiFeGaCo single crystal of ferromagnetic shape memory alloy (FSMA) subjected to subsequent loading-unloading compression cycles. The stress-strain parameters were obtained by mechanical and laser extensometers, whereas infrared measurement system (IR) enabled measurement of the sample temperature during the SMA deformation process. The obtained thermograms exposure localized character of the stress-induced martensitic transformation (SIMT), initiating in form of inclined bands of higher temperature and developing throughout the sample. High repeatability of both mechanical and temperature changes obtained in the subsequent loading cycles indicates good thermomechanical properties of the FSMA crystal and confirms high accuracy of the measurement.

2. Results and discussion

Ferromagnetic shape memory alloys discovered by Ullakko (1996) exhibit magnetic field- or stress-induced reversible strains of up to 10% and can operate with 50–100 Hz frequency [1]. Similarly to classical SMA, these alloys are characterized by a high-symmetry cubic structure in the high-temperature phase and a low-symmetry tetragonal structure in the low-temperature phase. The goal of the research was to investigate the NiFeGaCo single crystal behavior in subsequent compression loading cycles and check whether the SIMT occurs macroscopically homogeneously or not. And if the transformation is localized, how it nucleates and develops. As a result, it was found that during the first cycle of the loading a band inclined by over 45° and characterized by higher temperature by approximately 0.4 K appeared manifesting localized character of the transformation (Fig. 1a). At higher strain a second family of bands appears, emerging at the angle close to 90° according to the loading direction (Fig. 1b), followed by many transformation bands developing towards the upper grip of the testing machine (Fig. 1c). After reaching the grip area, a strong band in the upper part of the sample emerged developing again at the

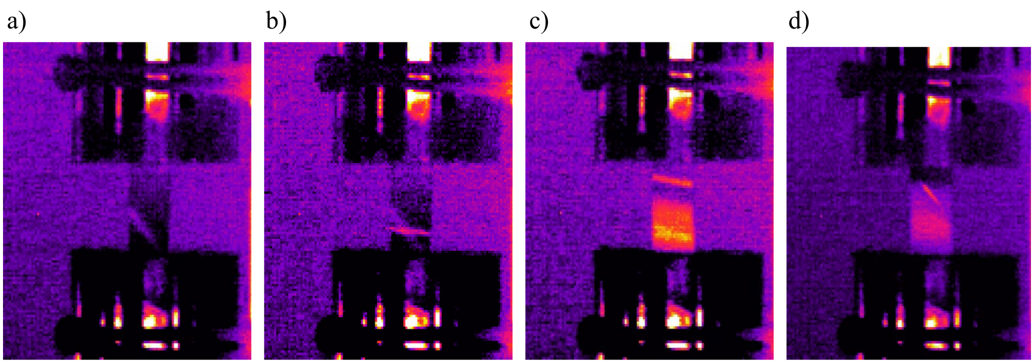

Fig. 1. Subsequent stages of FSMA single crystal loading shown in infrared: a) 1st transformation band, b) 1st and 2nd bands, c) many developing bands, d) a band developing from upper grip.

angle close to 45° (Fig. 1d). Similar localization effects were recorded in the subsequent loading-unloading cycles. The bands behavior seams to reflect a compromise between the alloy structure and the sample boundary conditions.

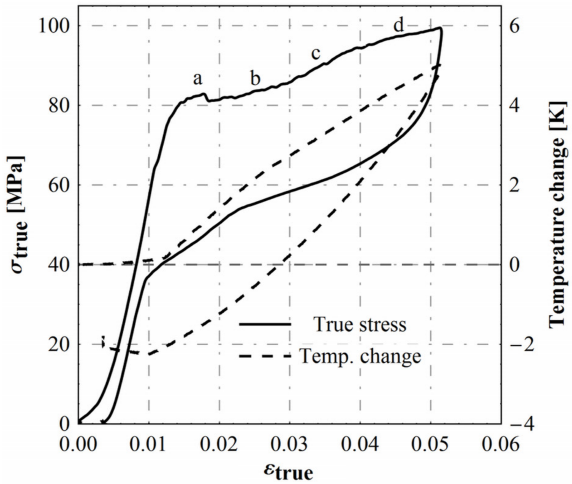

Fig. 2. Stress and temperature change vs. strain curve for 1st cycle of FSMA single crystal loading; a, b, c, d denote subsequent transformation stages shown in thermograms presented in Fig. 1.

Nucleation and development of the bands are especially valuable in the case of single SMA crystal, since the localization phenomena are not influenced by the grains and by the grain boundaries interactions. Due to that the observed effects are almost direct related to the SIMT mechanisms, according to its thermodynamics and the SMA microstructure. The reverse transformation is also not uniform; however the recorded localization effects are not so significant, like observed during the forward transformation. Shape memory alloys are very sensitive to the temperature. Therefore, the awareness of the stress and temperature changes accompanied the martensitic transformation is important for their thermodynamics study. In order to estimate the global heat effects, related to the transformation, average values of the sample temperature were calculated and compared to the stress vs. strain in the presented diagrams (Fig. 2) [3]. The values of the maximal temperature changes related to the exothermic martensitic forward transformation and measured in non-contact manner by high-performance IR camera are about 4.6 K. After the unloading, the sample temperature drop below its initial state by approximately 2.2 K (Fig. 2). These thermomechanical coupling effects, observed in SMA and confirmed in FSMA, are important for developing other direction of the alloys applications as cooling elements and will be a subject of our future research.

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