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# THERMOMECHANICAL ANALYSIS OF SHAPE MEMORY POLYMER UNDER CYCLIC LOADING AND RELAXATION CONDITIONS

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## 1. INTRODUCTION

Experimental evaluation and modeling of a new polyurethane shape memory polymer (SMP) subjected to cyclic tension and stress-relaxation tests are presented. The influence of effects of thermomechanical couplings on the SMP thermomechanical behaviour for various strain rates was studied, basing on the sample temperature changes measured by a fast and sensitive infrared camera. The constitutive model valid in finite strain regime was developed following [5]. In the proposed approach SMP is described as a two-phase material composed of hyperelastic rubbery phase and elastic-viscoplastic glassy phase while the volume content of phases is specified by the current temperature.

## 2. RESULTS AND DISCUSSION

The results of dynamic mechanical analysis (DMA) confirm the SMP shape memory properties: $T_g$ = 19°C, elastic modulus $E_g$' = 1500 MPa, rubber modulus $E_r$' = 15 MPa [1, 2]. First, the tension test was performed till almost the sample rupture (Fig. 1). The initial strain was accompanied by a small drop in temperature, called thermoelastic effect, related to the material yield point [3, 4]. At higher strains, the stress and temperature significantly increase due to reorientation of the polymer molecular chains [2].

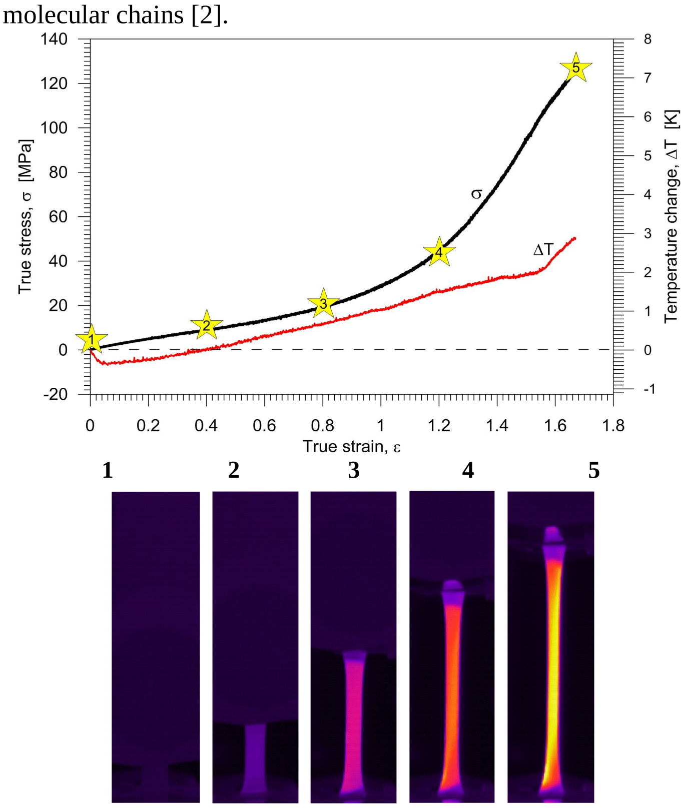


Fig. 1. Stress $\sigma$ and temperature changes $\Delta T$ of SMP subjected to tension with strain rate 2x10$^{-2}$s$^{-1}$ till almost the sample rupture. Numbered stars show the subsequent deformation stages presented in the sequences of thermal images below

Experimental results of cyclic tension tests and corresponding predictions of the model are presented in Fig. 2. It is seen that in the present form model is not yet able to capture material behaviour in the subsequent cycles. Some modification of the approach is necessary and is being currently performed in this respect.

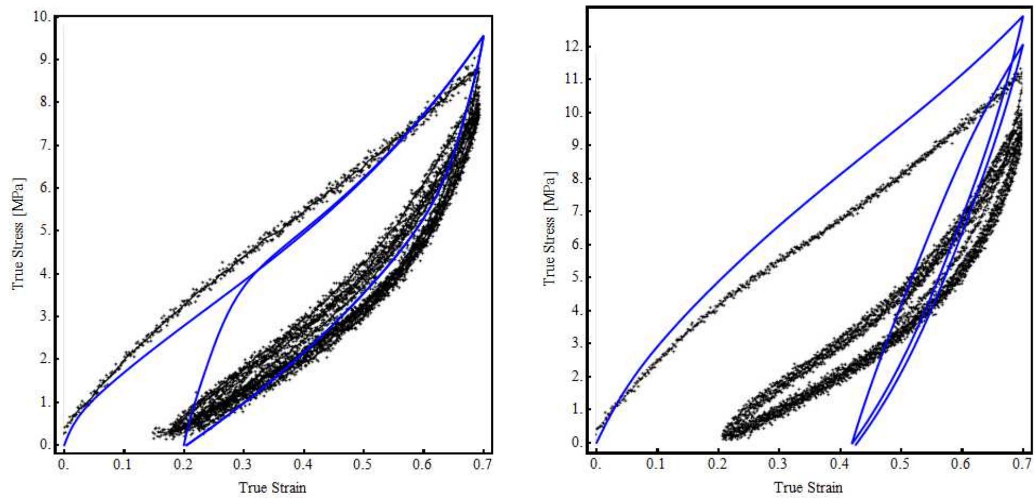


Fig. 2. Loading-unloading tension with strain rates $5x10^{-3}s^{-1}$ (left), $5x10^{-2}s^{-1}$ (right); black line - experiment, blue -model

The SMP stress-relaxation program was performed at the true strain of 1.2 with 3 min. relaxation break. Mechanical and thermal characteristics at strain rates: $2x10^{-2}s^{-1}$, $2x10^{-1}s^{-1}$, $2x10^{0}s^{-1}$ and $1x10^{1}s^{-1}$ are shown in Fig. 3.

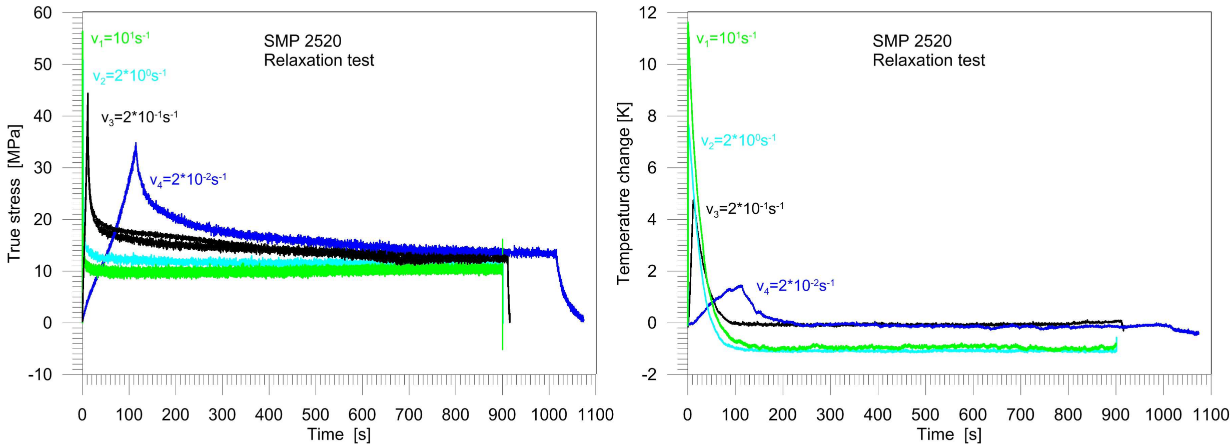


Fig. 3. Stress and temperature changes vs. time obtained during stress-relaxation test at various strain rates

It is seen that at lower strain rate the time needed to reach the constant stress level is longer. This can be related to various mechanisms of the deformation acting within the thermodynamic state caused by loading at various strain rates.

## 3. CONCLUSION

Experimental results and modelling have shown that the SMP deformation process strongly depends on the strain rate, much stronger than for metals and alloys [1, 3, 4]. At higher strain rate the higher stress and temperature changes were obtained, since the deformation process was more dynamic and has occurred in almost adiabatic conditions. It was shown that during the loading various deformation mechanisms are active at various strain rates. The constitutive model is able to reproduce satisfactorily such material behaviour in the first loading-unloading cycle and in relaxation process (comparison not shown here), however further work is needed in order to improve its predictions in subsequent cycles.


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