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Mechanical and Infrared Thermography Analysis of Shape Memory Polyurethane

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Introduction

Initial experimental evaluation of a new polyurethane shape memory polymer (PU-SMP) subjected to uniaxial tension carried out at different strain rates is presented. The stress and strain data were recorded and temperature changes from the SMP specimen surface was determined using fast and sensitive infrared camera. Basing on the mechanical characteristics and their relevant temperature changes, the SMP thermomechanical properties have been studied. Influence of the strain rate on the SMP temperature, its structure and behaviour are discussed. Identification of the PU-SMP parameters for one-dimensional rheological model proposed by Tobushi *et. al.* will be performed.

Experimental Results and Discussion

In order to learn more about the new polymer, a dynamic mechanical analysis (DMA) was performed [1]. The DMA was carried out in tension with frequency of force oscillation 1 Hz and heating rate 2°C/min. Results shown in Table 1 suggest that the PU-SMP material fulfills some preliminary demands to function as shape memory polymer. Namely, a high glass elastic modulus E_g' (1500 MPa), proper value of the rubber modulus E_r' (15 MPa) and a high ratio of E_g'/E_r' (100) were obtained. The T_g value taken as the midpoint of glass transition region is 19°C.

Table 1. Results of DMA obtained for polyurethane shape memory polymer denoted by MM 2520

Sample	E'_g [MPa]	T_g (as tan δ peak) [°C]	E'_r [MPa]	E'_g/E'_r
MM 2520	1500	19	15	100

Schematic of investigation of PU-SMP mechanical characteristics and temperature changes is shown in Fig. 1.

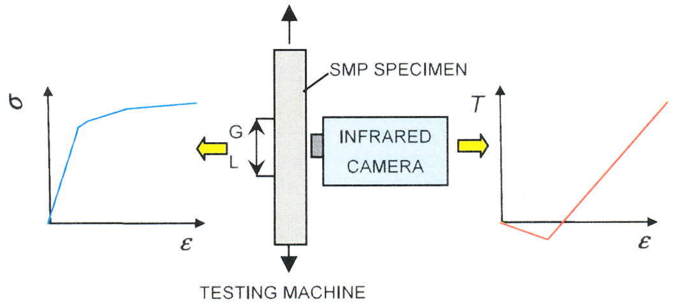

Figure 1. Schematic diagram of investigation of SMP mechanical characteristics and temperature changes

The results, namely a true stress (left) and specimen temperature change (right) versus true strain, obtained during tension at room temperature (23 °C) with strain rates $2x10^{-1}s^{-1}$, $2x10^{0}s^{-1}$ and $2x10^{1}s^{-1}$ till rupture, are shown in Fig. 2.

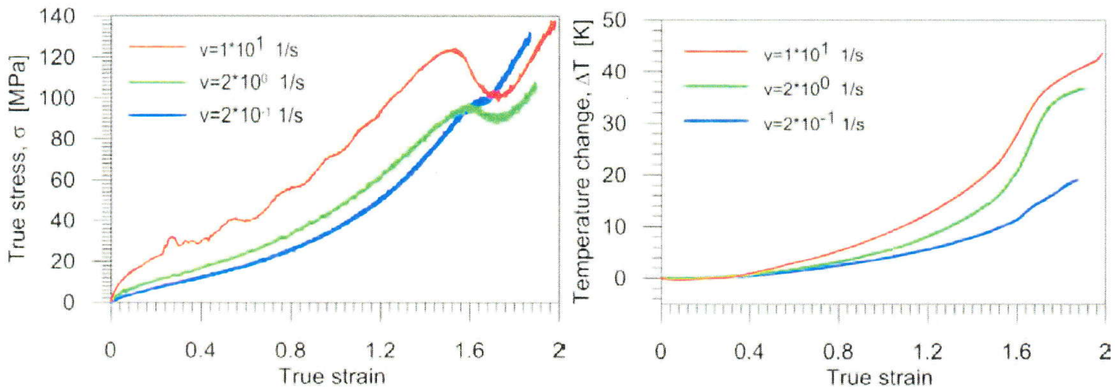

Figure 2. Stress vs. strain (left) and temperature change vs. strain (right) for SMP tension with various strain rates

It is seen that the initial monotonic stress increase, related to the reorientation of the polyurethane molecular chains [1], is followed by stress drop noticed at strain value of approximately 1.4. The stress drop can be related to the SMP crystallization phenomenon, observed as the sample whitening. The ultimate true strains are over 1.8. The higher strain rate, the higher temperature changes were obtained, since the process was more close to adiabatic conditions. The maximal values, recorded to the sample rupture, were 18 K for $2x10^{-1}s^{-1}$, 37 K for $2x10^{0}s^{-1}$ and 44 K for $10^{1}s^{-1}$.

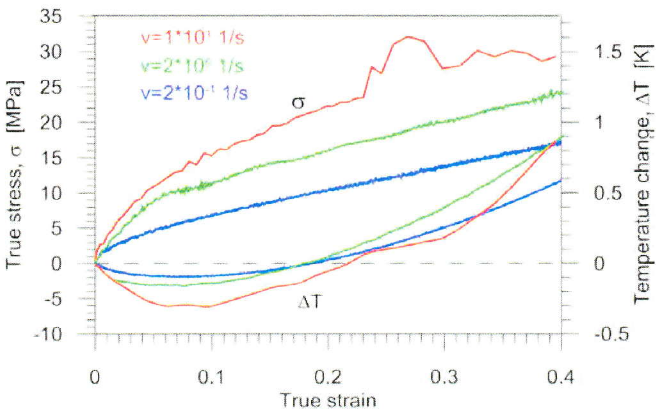

Figure 3. Stress σ and temperature change ΔT versus strain for SMP initial tension with various strain rates

The initial stage of the SMP deformation is presented in Fig. 3. The yield strength increases upon increase of the strain rate. The initial elastic strain is accompanied by a temperature decrease - thermoelastic effect. It is worth noting that the maximum temperature drop, related to the material yield point [2], also depends on the strain rate.

Acknowledgments

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References

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[2] Pieczyska E.A., Nowacki W.K., Tobushi H., Hayashi S., Thermomechanical properties of shape memory polymer subjected to tension in various conditions, *QIRT Journal*, Vol. 6 (2010) pp.189 - 205.