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THERMOMECHANICAL ANALYSIS OF SHAPE MEMORY POLYURETHANE

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ABSTRACT

This paper presents experimental evaluation of a new polyurethane shape memory polymer (PU-SMP) produced by *SMP Technologies Inc.* It discusses mechanical characteristics and temperature changes of the SMP specimens subjected to tension test performed at room temperature with various strain rates. Basing on the mechanical data and the relevant temperature changes, we have studied the thermomechanical properties of the PU-SMP and influence of the strain rate on the strain localization behavior. Finally, we have identified the material parameters for the one-dimensional rheological model of the SMP.

Keywords: shape memory polyurethane, tension test, dynamic mechanical analysis, infrared camera, temperature change, thermomechanical properties, rheological model.

INTRODUCTION

In SMPs, the elastic modulus and the yield stress are high at temperatures below the glass transition temperature T_g and low above T_g. If SMPs are deformed at temperatures above T_g and cooled down to temperatures below T_g by holding the deformed shape constant, the deformed shape is fixed and SMPs can carry large load. If the shape-fixed SMP element is heated up to temperatures above T_g under no load, the original shape is recovered. The shape memory property appears based on the glass transition in which the characteristics of molecular motion vary depending on the variation in temperature. Among the SMPs, the polyurethane shape memory polymer (PU-SMP) has been practically used (Tobushi, 2011). In this research we have studied thermomechanical properties of the PU-SMP.

RESULTS AND CONCLUSIONS

The obtained results of dynamic mechanical analysis (DMA) show that the PU-SMP glass transition temperature T_g value is 19°C, the glass elastic modulus E_g' is 1500 MPa and the rubber modulus E_r' is 15 MPa. The high value of E_g', proper value of E_r' and a high ratio of E_g'/E_r' (100) suggest that the material fulfills some preliminary demands to function as SMP.

Mechanical characteristics and temperature changes of the PU-SMP specimens subjected to tension test performed in different conditions have been clarified using a high quality testing machine and a fast infrared camera. Photographs of the sample (measurement base 15 mm) in grips of the testing machine obtained during the tension process is shown in Fig.1. Stress and temperature change of the SMP sample for strain rate $2x10^0 s^{-1}$ till rupture are shown in Fig. 2.

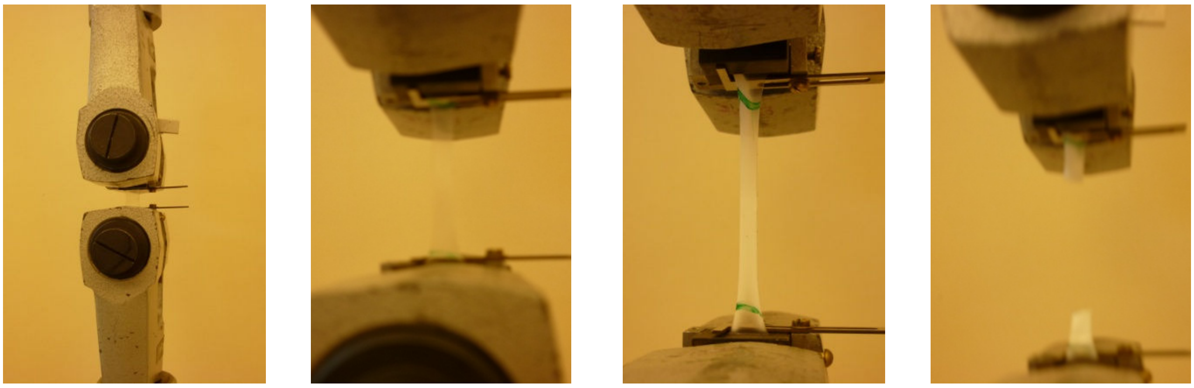

Fig. 1 - Photograph of PU-SMP sample in grips of testing machine during various stages of the tensile process

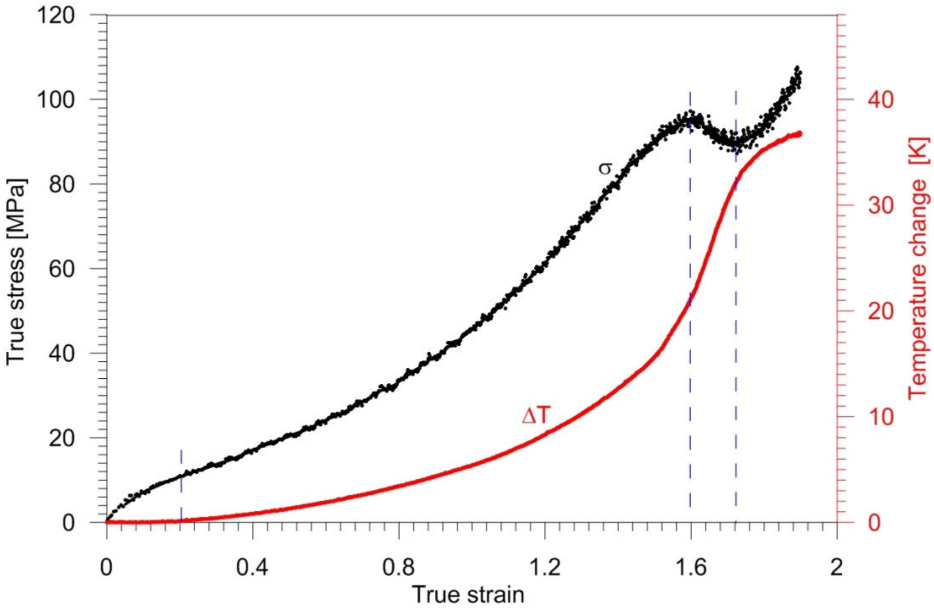

Fig. 2 - Stress σ and temperature change ΔT of the SMP sample obtained for strain rate $2x10^0s^{-1}$ till rupture

The observed strain range in the stress and temperature vs. strain curves may be divided into four stages. Stage I is the initial elastic deformation, stage II is the plastic deformation, related to the increase of the sample stress and temperature. In stage III the stress decreases while the temperature significantly increases, which can manifest change in the SMP structure, i.e. development of crystallographic phase (crazing). Final stage IV precedes the sample rupture.

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