THERMOMECHANICAL ANALYSIS OF SHAPE MEMORY POLYURETHANE

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ABSTRACT

This paper presents experimental evaluation of a new polyurethane shape memory polymer (PUbSMP) 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 PUbSMP 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 \( 2\times10^3 \text{s}^{-1} \) till rupture are shown in Fig. 2.
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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**REFERENCES**