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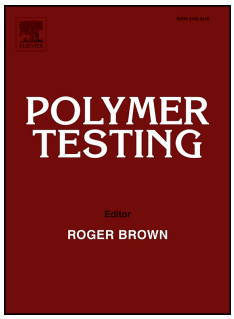

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Hui Guo, Weiguo Guo, Alireza V. Amirkhizi, Ruilu Zou, Kangbo Yuan

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Experimental investigation and modeling of mechanical behaviors of polyurea over wide ranges of strain rates and temperatures

Hui Guo [a], Weiguo Guo [a,*], Alireza V. Amirkhizi [b], Ruilu Zou [a], Kangbo Yuan [a]

[a] School of Aeronautics, Northwestern Polytechnical University, Xi'an, 710072, China. E-mail: weiguo@nwpu.edu.cn

[b] Department of Mechanical Engineering, University of Massachusetts, Lowell, MA, 01854, USA.

Abstract: Theoretical and experimental studies on the compressive mechanical behavior of two formulations of polyurea under uniaxial stress state and quasi-one dimensional strain state are conducted over the temperature range of -40°C -+20°C and the strain rate range of 0.001/s-12000/s. The stress-strain behavior of polyurea samples is established at different strain rates and temperatures, and key mechanical properties of the materials are determined. The experimental results show the significant sensitivity of compressive stress-strain curves of polyurea to strain rate and temperature within and beyond linear viscoelastic regime. In addition, the mechanical properties of PU605 (Versalink P-650 reacted with 105% molar equivalent Isonate 143L) are compared to those of PU105 (Versalink P-1000 reacted with 105% molar equivalent Isonate 143L). Based on the experimental results with confined pressure, a calculation method is presented which is available to study the bulk modulus of polyurea. Finally, a visco-hyperelastic constitutive model is developed to describe the nonlinear mechanical behavior of polyurea over a wide range of strain rates and temperatures.

Key words: Polyurea; Rate-dependence; Temperature-dependent; Confined pressure; Bulk modulus

1. Introduction

Improving the performance of protective structures against failure due to high rate loadings, including but not limited to blast and impact, has been on the forefront of materials research for a long time. However, the use of soft elastomeric coatings for the purpose of minimizing structural collapse, fragmentation, and erosion is comparatively a new endeavor. For example, recent studies have shown that applying a layer of polyurea backing to metal and other stiff plate-like structures significantly enhances the resistance to the impulsive loadings [1-3]. But up to now, the anti-impact mechanism of polyurea is still lack of study in depth and systematically. Only a few speculations include: (1) the elastomer layer delaying the onset of necking behavior of the metal in metal–elastomer bilayer plates [4, 5]; (2) the polyurea layer changing the propagation of stress wave and redirecting the energy [2, 6, 7, 8]; (3) the transition of polyurea between its rubbery-state and its glassy-state under high deformation-rate loading conditions improving the ballistic impact resistance of polyurea-coated structures/test plates [9, 10]. Therefore, the systematic study on the nonlinear mechanical behavior of polyurea at different strain rates has important significance for further design and optimization efforts.

Polyurea is a viscoelastic material; while it demonstrates behavior similar to hyperelastic materials especially at large deformations. With the increasing application of polyurea as coating more scholars have looked at its mechanical properties at high strain rate and large deformations. Yi et al. [11] studied the compressive mechanical properties of one polyurea and three polyurethane samples using the split Hopkinson pressure bar system. These samples demonstrated highly non-linear stress-strain relationships, indicating strong hysteresis and rate dependency. Subsequently, Sarva et al. [12] studied the mechanical properties of polyurea samples over a wide range of strain rates, from 10^{-3} to $10^{4}s^{-1}$, and found that the stress-strain curves of polyurea indicated a transition from rubber-like behavior at low strain rates to leather-like behavior at high strain rates. Meanwhile, Shim et al. [13] studied the