Chapter 17
Mechanical Characterization and Numerical Material Modeling of Polyurea

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Abstract The mechanical behavior of four unique blends of polyurea materials has been investigated through a combined experimental and computational study. Mechanical characterization of each material was evaluated under both tensile and compressive loading at strain rates ranging from 0.01 to 100 strains per second (1/s). Planar blast wave experiments utilizing a 40 mm light gas gun were also conducted which imparted strain rates up to 10^4 strains per second (1/s). The material testing results showed that stress-strain response is a function of loading, strain level, and strain rate. These results were utilized to define a non-linear rubber material model in Ls-Dyna which was validated against the test data through a series of "block" type simulations for each material. Each material model was shown to replicate both the tensile and compressive behavior as well as the strain rate dependence. The material models were subsequently extended to the simulations of the blast wave experiments. The blast wave simulations were shown to accurately capture wave propagation resulting from a shock type pressure loading as well as the stress magnitudes of the transmitted waves after passing through the respective polyurea materials. The current study has resulted in the mechanical characterization of four polyurea materials under tensile/compressive loading at increasing strain rates, a suitably validated numerical material model, and suitable correlations between experimental and simulation results.

Keywords Polyurea materials · Blast loading · Computational modeling · Material characterization · Strain rate effects

17.1 Material Characterization

Polyurea materials in general exhibit non-linear responses which differ under tensile and compressive loadings, as well as exhibit both strain and strain rate response dependence. Baseline material characterization for each of the four unique polyurea blends was conducted for tensile and compressive loading at strain rates from 0.01-to-100 1/s. The results of the mechanical characterization show that the materials in the current study exhibit unique responses under compressive and tensile loading, as well as a stiffening effect under increasing strain rate. The typical stress-strain response is shown in Fig. 17.1. The response of the materials under strain rates up to 10^4 1/s was studied through a series of gas gun experiments which produce uni-axial stress wave loading through the material thickness. A schematic of the gas gun experimental setup is shown in Fig. 17.2.

17.2 Experimental / Numerical Correlation

The finite element model of the gas gun target assembly is shown in Fig. 17.3 and includes the front aluminum cylinders, polyurea sample, and rear aluminum cylinders. Figure 17.4 presents the correlation between the experimental and numerical results for the front and back face PVDF gauges. From this figure it is seen that due to pressure loading on the front-face of the aluminum there is a dilatational stress wave that propagates through the aluminum cylinder and ultimately into the polyurea disk. The wave is nearly a stepwise shape characterized by a near instantaneous rise time, followed by a constant stress profile and a rapid decay as the wave passes through the gauge. It is shown that the model accurately captures both the

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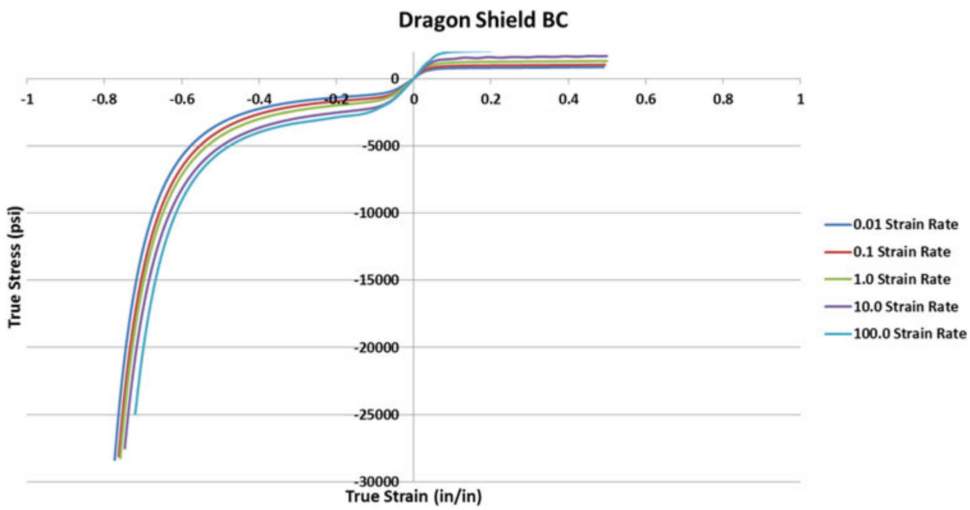

Fig. 17.1 Material characterization

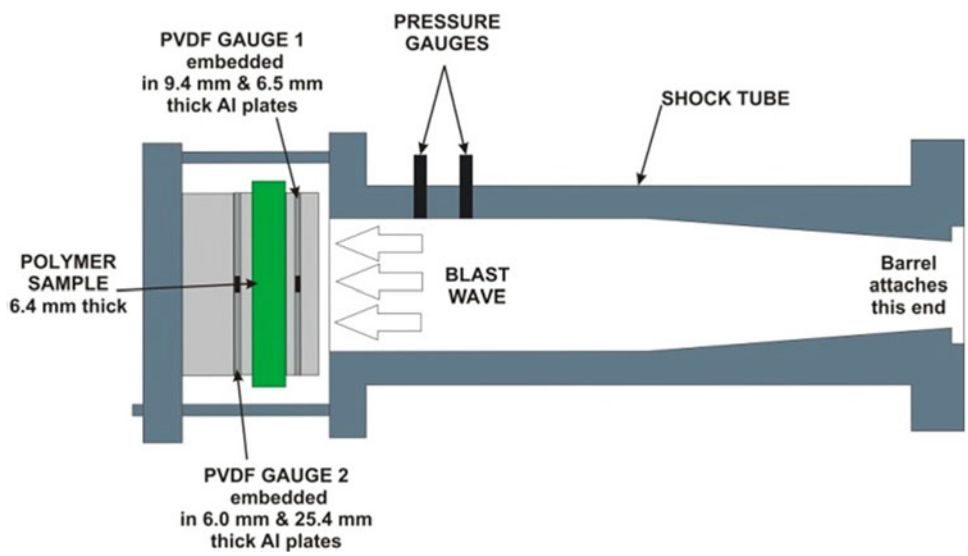

Fig. 17.2 Gas gun experimental schematic

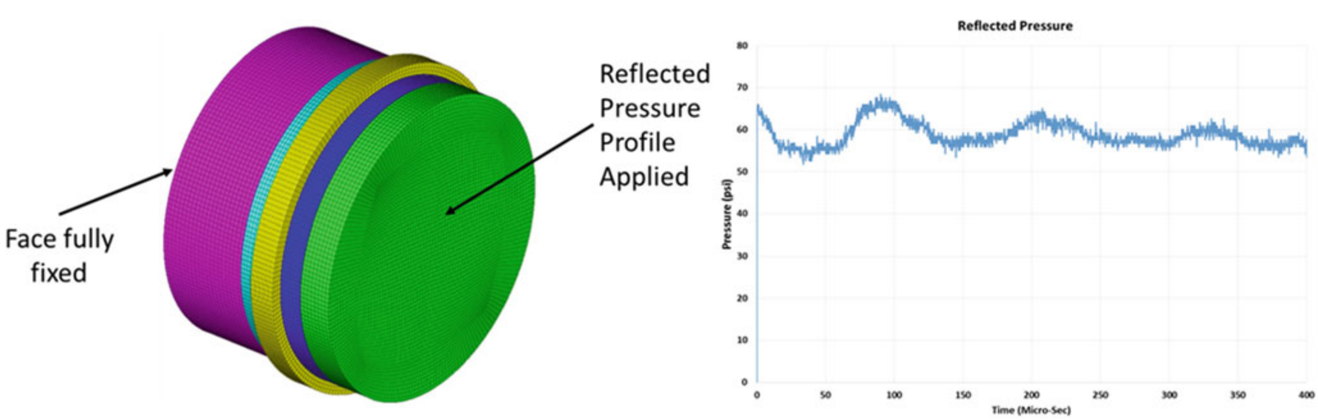

Fig. 17.3 Computational model schematic

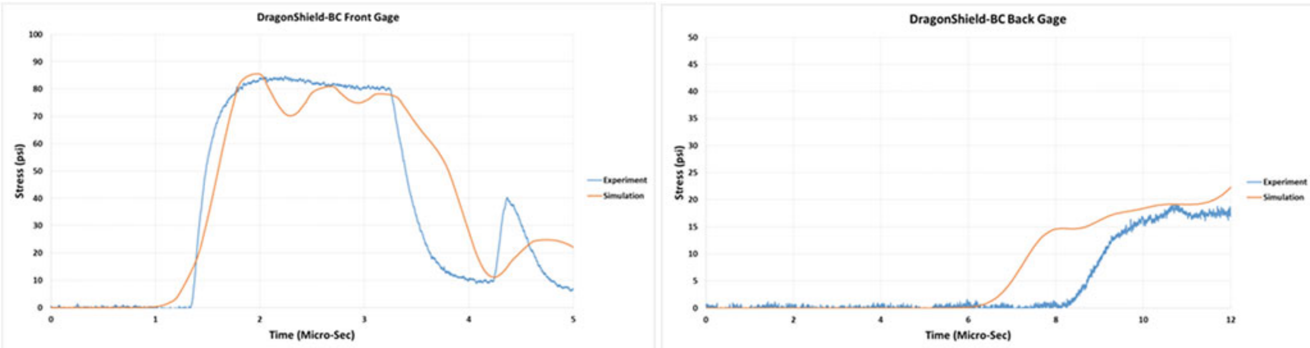

Fig. 17.4 PVDF stress gauge correlation

magnitude as well as the time duration of the incident stress wave in the forward aluminum cylinders and into the polyurea samples. The correlation of the transmitted wave, as recorded by the back face PVDF gauge, is also shown in Fig. 17.4. It is seen that the magnitude and general shape of the transmitted stress wave from the simulation is in good agreement with the experimental result. It is noted that the simulation does predict the arrival of stress wave at the PVDF gauge approximately 2 micro-sec sooner than is observed in the experiments. Based on these results, it is determined that the material models suitably predict the stress wave propagation through the material in terms of dispersion; however, there is a slight difference in wave speed.

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