A Polymer DOE and DoD Collaboration through the Joint Munitions Program

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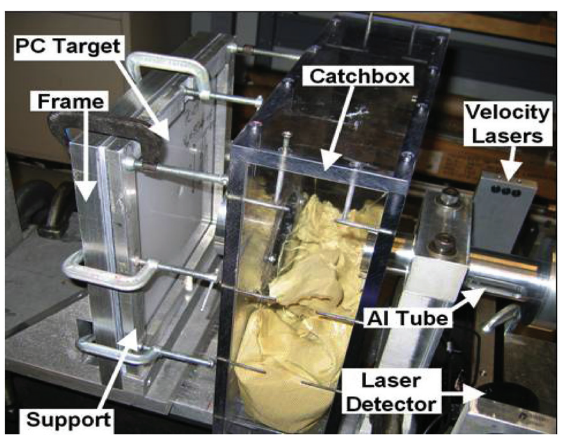
The Nuclear Weapons JMP fosters collaborations between DOE and DoD researchers working on problems of common interest between the two departments. In FY10 several collaborations involving ADTSC theoretical researchers, experimental groups in the MST and WX Divisions, and researchers in several DoD laboratories produced results that are noteworthy. For brevity only one illustrative effort will be highlighted: a collaboration with LANL and ARL researchers in Aberdeen, MD.

The goal of the collaboration between Department of Energy (DOE) and Department of Defense (DoD) researchers is to use LANL's expertise in polymer constitutive model development and Army Research Laboratory's (ARL) ballistic impact experimental capabilities to address issues of polymer impact, survivability to blast, and transparent armor performance. To generate the needed data, LANL's renowned experimental facilities in the MST and WX Divisions carried out an exhaustive suite of polymer characterization experiments, from which a model of glassy polymers was developed in T Division. The polymer model accurately captures the volumetric equation of state (including the non-equilibrium viscoelastic behavior), the uniaxial compression stress-strain response from quasi-static rate through rates of thousands per second (for example those obtained using the Split Hopkinson Pressure Bar experiment), plate impact measured Hugoniot, as well as a detailed match to the experimental shock velocity profiles, and the observed deformation of a polymer cylinder shot in Taylor impact experiments. Having implemented the glassy polymer model into finite element method (FEM) codes, simulations were then done to compare with the ARL experiments.

Fig. 1. ARL back-surface displacement impact experiment.



The experimental setup used by ARL researchers is shown in Fig. 1. The goal of the experiment is to measure the deformation field of a polymer plate (for example, polycarbonate [PC], also called ballistic glass) when impacted by a blunt steel projectile. The transient deformation field is measured by high-speed digital cameras, and is post-processed using a digital image correlation (DIC) technique to obtain the out-of-plane displacements.

The entire deformation field is recorded in the ARL experiments, but to make quantitative comparisons with the LANL glassy polymer model, it is advantageous to focus on the displacement at the point of impact. Figure 2 shows the side and top profiles of a simulation for the purpose of displaying the geometry. The polymer plate is ballistic glass and the projectile is hardened steel. Impact speeds of 30.5, 41.5, and 50.5 m/s were used in both the experiments and the simulations.

Figure 3 shows side-by-side comparisons of the experimental and theoretical displacement fields for the point of impact. Aside from the magnitude of the initial displacement for the 50.5 m/s shot at about 1 ms, the agreement with the experiment is very good. This includes the late-time dissipation of the peaks and phase lag of the ringing for the lower impact speeds. This work reveals that LANL's glassy polymer is a very good candidate for transparent armor design.

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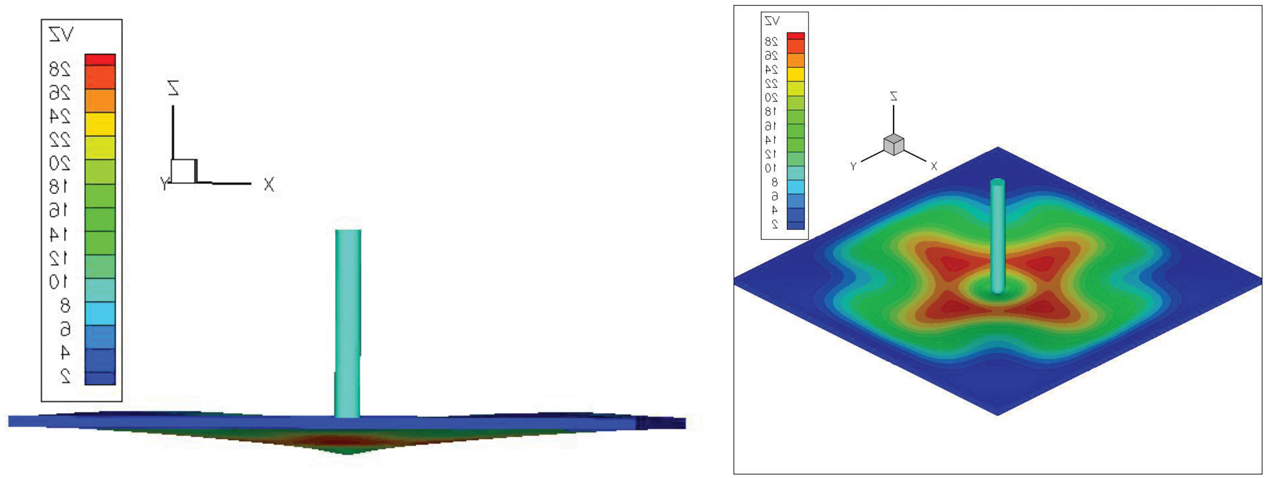

Fig. 2. Side and top profiles of the ballistic impact simulations. The displacement at the point of impact is clear from the left-hand figure. The color scheme is the velocity field in the z direction.

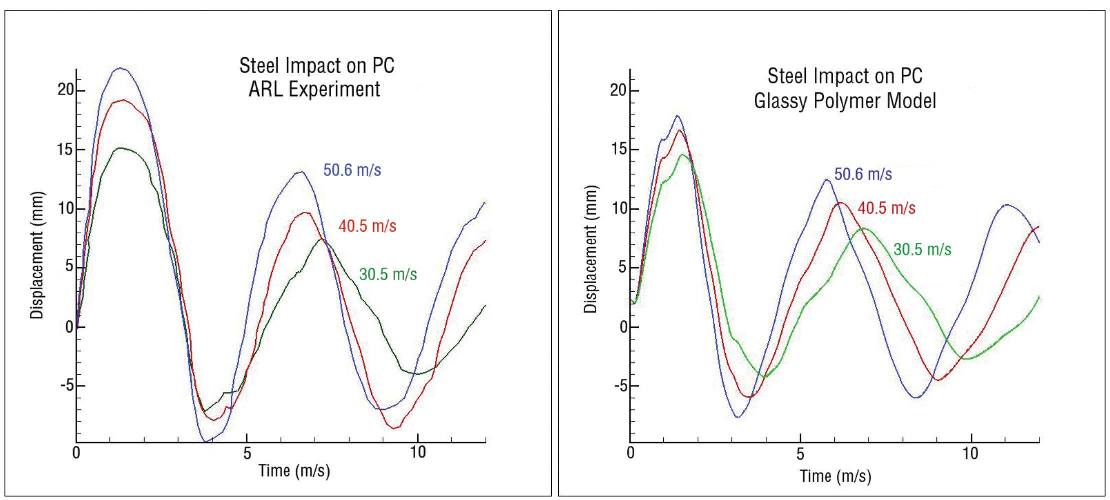

Fig. 3. Experimental displacement at the impact point as a function of time from the ARL experiment (left) and the LANL glassy polymer model (right).

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