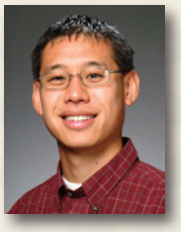
# Plasticity at High Pressures and Strain Rates using Oblique-Impact Isentropic-Compression Experiments



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Various aspects of LLNL's national security mission depend on accurate computer code simulations of materials in high strain-rate plastic flow (*i. e.*, nonreversible deformation) under conditions of high hydrostatic pressures. While progress has been made in recent years, especially at the extreme cases of pressure and strain rate, there is still an uncertainty in understanding the strength of materials under conditions of combined high strain rate ($10^4$ to $10^6$ $s^{-1}$) and high pressure (1 to 100 GPa).

Current strength models used in simulations include some physically based models such as the Mechanical Threshold Stress formulation, which has over 20 parameters. The uncertainty in the values for these parameters as well as values for the parameters in other physically based models is under question due to the inherent difficulties in conducting and extracting high-quality experimental data in the high pressure and high strain rate regimes. The experimental studies of material strength at these pressure and strain rate regimes will further the understanding of the underlying physical strength mechanisms needed for accurate material strength models.

## Project Goals

The goal of this project is to develop an oblique-impact compression experiment using windowed interferometry (Fig. 1) to measure the strength of materials under a condition of combined high strain rate ($10^4$ to $10^6$ $s^{-1}$) and high pressure (1 to 100 GPa). The oblique impact allows for a measurement of the strength properties under pressure, and by using windowed interferometry, the pressure is maintained during the measurement and higher pressures can potentially be achieved. The strength data will then be used to refine and enhance current strength models. When completed, this work will increase the Laboratory's ability to develop predictive strength models for use in computer code simulations.

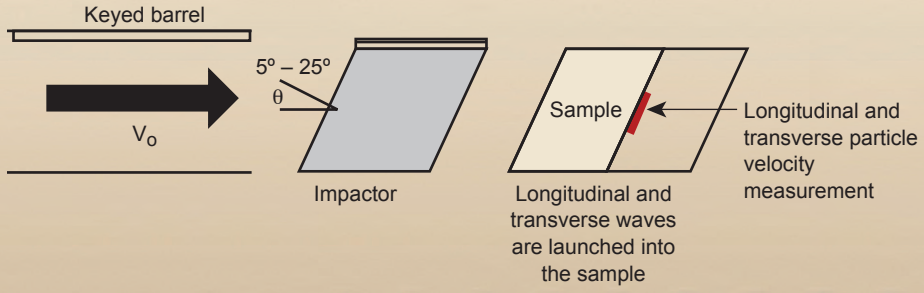


**Figure 1.** Oblique-Impact compression experiment using windowed interferometry.

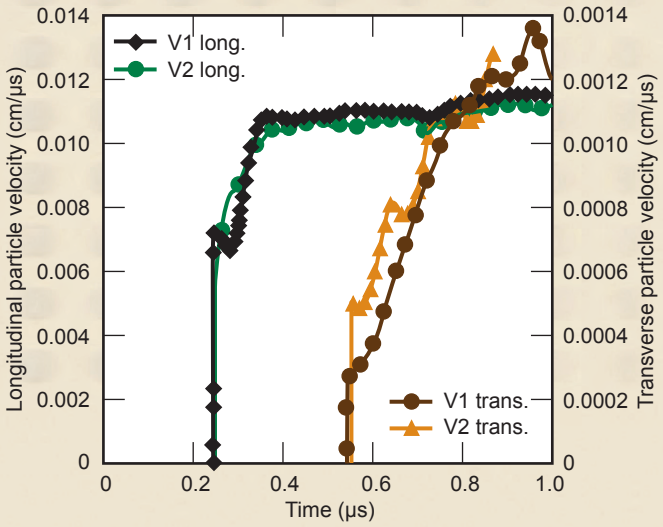


**Figure 2.** Experimental longitudinal and transverse waves measured at the vanadium/sapphire interface for two samples.

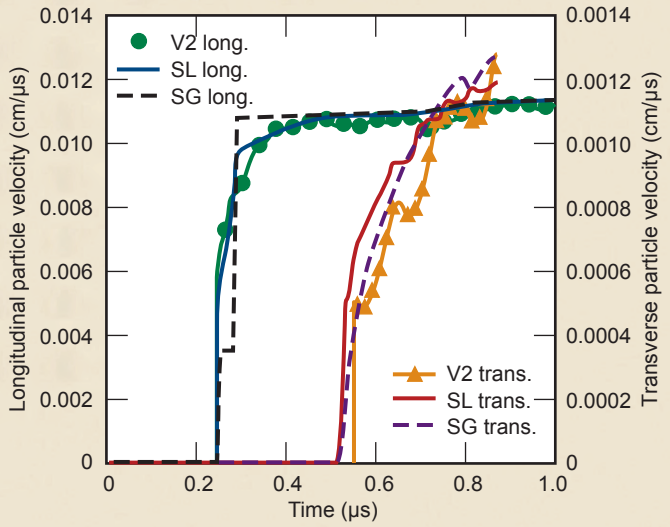


**Figure 3.** Comparison between the experimental data and the simulations results using two strength models, the Steinberg-Lund (SL) and the Steinberg-Guinan (SG) models.

## Relevance to LLNL Mission

This experiment, including understanding and simulating the strength of materials under dynamic loading conditions, is directly aligned with the Materials Pillar within LLNL's Science and Technology Five Year Strategic Roadmap. In addition, this work intersects with the roadmap's Stockpile Stewardship Science thrust area.

## FY2009 Accomplishments and Results

In this fiscal year, we have performed experiments on vanadium (V) samples, which allowed us to achieve a more reproducible velocity signal than previous experiments on copper. In addition, simulations were performed using ALE3D to examine how different strength models compare with the experimental data.

**Experimental results.** We have performed experiments on V samples backed by a sapphire window on the 2-in. keyed-barrel gas gun at Brown University. The results from the two experiments, both using a 1.5-mm-thick sample backed by a 10-mm sapphire window, are shown in Fig. 2. The samples were impacted at 200 m/s with a Ta-10% W target. In comparison to previous data, the transverse velocity signals are much smoother with less noise. While there is a slight discrepancy between the two experiments in the initial portion of the transverse wave signals, the fact that the transverse velocities reach a similar level at later times is indicative that the strength of the two materials is nominally the same.

**Simulation results.** The experimental results have been compared with the simulation results using two models, the Steinberg-Guinan (SG) model, and the Steinberg-Lund (SL) model, as shown in Fig. 3. With both models the experimental results can be reproduced by using parameters that predict a flow stress of approximately 600 MPa at the time of the arrival of the transverse wave. The main difference between the two models is that the SG is strain rate independent while the SL model has strain rate dependency built into the model. The strain rate dependence in the SL model allows the model to better match the experimental longitudinal wave data, as well as the sharp increase seen in the experimental data when the transverse wave arrives.

## Related References

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