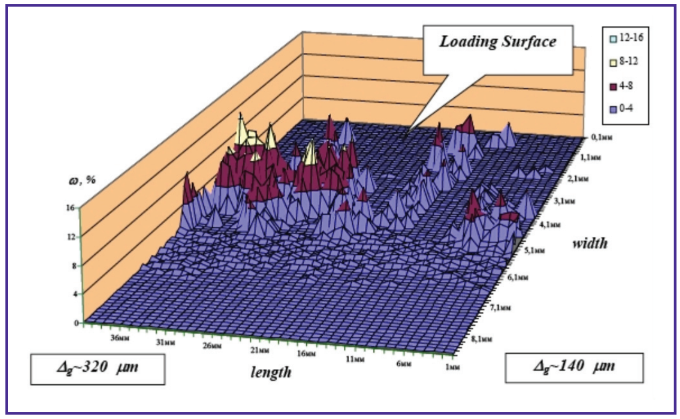
Los Alamos NATIONAL LABORATORY

Experimental-Theoretical-Numerical Studies of Constitutive Behavior and Damage Mechanics

Principal Investigators: Marvin A. Zocher, Dean L. Preston, George T. Gray III (LANL), and Olga N. Ignatova (VNIIEF)

Project Description



Distribution of damage in sample subjected to variable-thickness gap test.

The formulation of mathematical models capable of predicting the behavior of materials when subjected to an arbitrary thermomechanical loading environment is an area of active research. It includes models for predicting the constitutive response of the material and the initiation and evolution of damage. Successful development of such predictive models inherently relies on experimental data obtained from laboratory tests carefully constructed to evaluate some particular thermomechanical response or mechanism. These experimental results then support the development of theoretical models, which can be implemented into a variety of numerical methods, thereby providing general-purpose predictive tools.

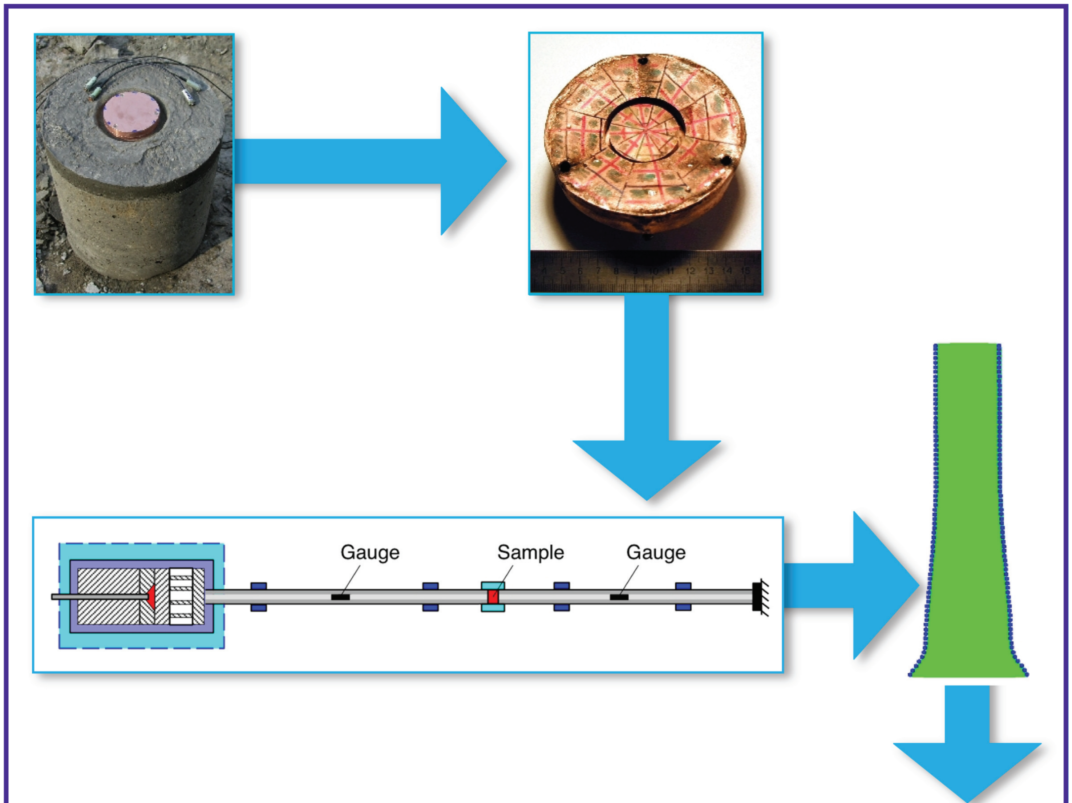
A variety of experimental techniques will be used in support of this work (e.g., split Hopkinson pressure bar, Taylor cylinder, flyer plate impact, and quasi-isentropic and shock loading by the expansion of HE detonation products).

Issues to be investigated include the effect of grain size on constitutive behavior and the mechanics of damage, the effect of deformation localization on constitutive behavior and the mechanics of damage, the evolutionary processes involved in both the time and spatial dependence of grain morphology and deformation localization, time scale effects related to transient thermal softening associated with deformation localization — both as it affects constitutive behavior and as it affects damage initiation and evolution, the mechanisms involved in damage compaction and the apparent "healing" of previously damaged materials, and the effects of such "healing" on subsequent constitutive behavior and sequel damage evolution.

Metallographic analysis will be used extensively to assess microstructural morphologies. Existing material models will likely be improved. It is possible that entirely new material models will be developed. Extensive numerical analysis will be conducted to assess the validity of numerical models.

Technical Purpose and Benefits

The development of better predictive capability is essential if LANL is to meet its obligations to NNSA and the country. Models that more accurately predict constitutive behavior and the mechanics of damage are of critical importance. Under this project, a number of new models have already been produced. Two examples are (1) a new constitutive model that accounts for evolving grain structure and (2) a new constitutive model that accounts for deformation localization and the effects thereof (extremely critical in high strain rate environments). The second of these two new models is nonlocal, accounting for issues of relaxation time and length scale. Some entirely new and unique damage experiments have been developed under this work, which are enabling the development of improved damage models. This work supports the objectives of the NNSA and both research institutions (LANL and VNIIEF) as they endeavor to improve their predictive capabilities in two critical areas — constitutive behavior and the mechanics of damage.



$$\sigma_{ij} = \sigma_{ij}\left\{\epsilon_{kl}, \dot{\epsilon}_{kl}, T, \ldots\right\}$$

Preconditioning of material to alter its microstructure: one of the approaches being taken in the development of constitutive models that can account for evolving grain morphology and localization effects (in image on right) — green is predicted final shape; blue is measured final shape.

ВНИИ
VNIIEF

Collaboration between Los Alamos National Laboratory (LANL), Los Alamos, NM, USA, and the Russian Federal Nuclear Center – All Russian Research Institute of Experimental Physics (RFNC-VNIIEF), Sarov, Russia

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