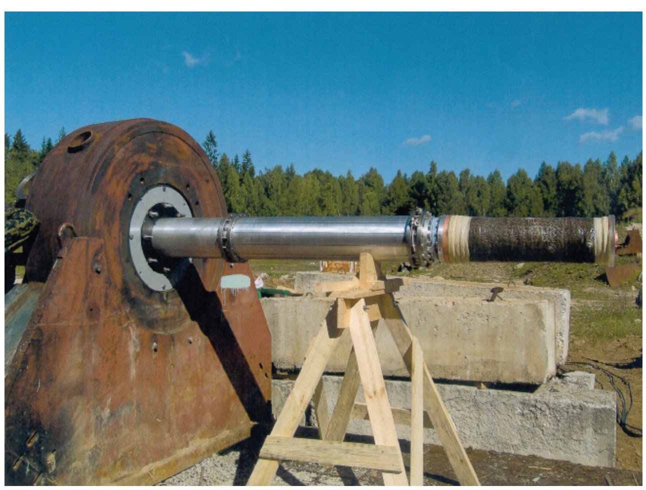
Exploration of Damage Mechanisms in Cylindrical Geometry

Principal Investigators: Ann M. Kaul (LANL) and Andre V. Ivanovsky (VNIIEF)

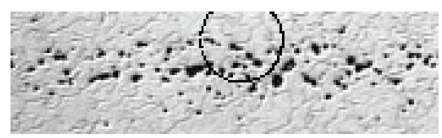
Project Description

Another application of liner technology is to explore spallation damage, a typical method of failure for ductile materials, resulting from the nucleation, growth, and coalescence of voids caused by high tensile stress. The development of mathematical models capable of accurately predicting the behavior of damage in metals in complex stress states has been an active research area for many years. While much progress has been made in this area (for example, the tensile elastic plastic, TEPLA, model), two major areas of research remain: (1) the mechanisms that control the onset of void formation and growth (damage initiation) and (2) the strength properties of a damaged material if the material is recompressed and the cracks closed. Additionally, while a significant body of data exists from one-dimensional experiments, very few experiments have been conducted in convergent configurations. Such data would allow experimental validation of the multidimensional aspects of existing models.

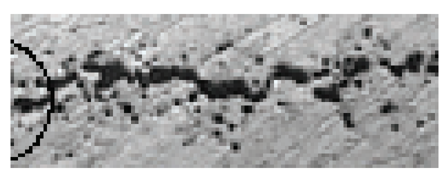
At the same time, a converging geometry allows access to non-one-dimensional stress states and the opportunity to explore void closure and material properties as the native material behind the damaged region is reaccelerated in the later stages of the cylindrical implosion. Magnetically driven implosions provide a degree of controllability and precision not available with other cylindrical implosion techniques. These experiments provide data in a convergent geometry that overlaps with and extends planar gas-gun damage data. VNIIEF researchers are acknowledged experts in the fielding of magnetically driven implosions. Additionally, recovery of the experimental sample is an important feature of these experiments, and VNIIEF has unparalleled expertise in recovery techniques for explosively powered experiments. Therefore, LANL designs and manufactures the experimental loads, while VNIIEF provides the system to power the experiment and protect the load. Diagnostic measurements are conducted jointly by both laboratories.



VNIIEF generator and load protection.



RD-1b, incipient spallation damage.



RD-1a, full crack formation.

The main objective of this effort is to obtain damage data in a (presumably) well understood material for development and validation of damage models; specifically, obtaining data near the damage initiation threshold and under conditions where voids close after damage. The first experimental series produced shocks with strengths near the damage initiation threshold, comparable to those produced in planar gas gun experiments, allowing comparison of material behavior in planar and cylindrical geometries. The second series of experiments demonstrated reacceleration and re-compaction, again near the damage threshold to investigate the behavior of recollected spallation-damaged material.

Data from these experiments are incorporated into the Tonks Ductile Failure Model (a research version of TEPLA). This model describes spallation situations with high tensile stresses and addresses the nucleation, growth, and coalescence of microvoids in ductile metals, which preferentially fail by this means. Future results will be used to develop the Tonks "Crush-up" Model, used to describe behavior of material re-collected after damage.

Technical Purpose and Benefits

The development of better predictive capability is essential if LANL is to meet its obligations to NNSA and the nation. Current damage models do not account for some of the fundamental mechanisms that lead to failure. Under this project, data are being produced to validate and improve damage models and to develop models of post-damage material behavior. This work supports the objectives of the NNSA and both research institutions (LANL and VNIIEF) as they endeavor to improve their predictive capabilities in the area of damage mechanics.

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

A Publication of the Office of Advanced Simulation & Computing, NNSA Defense Programs. SAND 2007-4400P
Issued by Sandia National Laboratories for NNSA's Office of Advanced Simulation & Computing, NA-114. Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.