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DYNAMIC COMPRESSION OF SOLIDS: MECHANICS CHALLENGES AND OPPORTUNITIES

Yogendra M. Gupta
Washington State University
Institute for Shock Physics and Department of Physics
PO Box 642814
Pullman, WA 99164-2814
ymgupta@wsu.edu
http://www.shock.wsu.edu

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ABSTRACT

Dynamic loading (shock wave and shockless compression) experiments subject materials to unique conditions (very large compressions, high temperatures, and large deformations) on very short time scales (ps to μs) resulting in a rich array of physical and chemical changes. Additionally, the macroscopic condition of uniaxial strain is exactly satisfied in these experiments. The scientific focus of this presentation is for peak longitudinal stresses below 50 GPa. The extreme conditions encountered under dynamic loading provide an excellent opportunity to explore the delicate balance between mechanical and thermal energies by examining how this balance governs a wide variety of physical and chemical phenomena in the condensed state. The short times, inherent in dynamic loading experiments, result in the kinetics playing an important role in determining the governing mechanisms and the attainment of metastable states, beyond just thermodynamic considerations.

Because of the unique loading conditions indicated above, dynamic experiments are ideally suited to examine a broad range of condensed matter phenomena: structural changes; deformation and fracture; and chemical reactions including bonding and energetics. Furthermore, the very short time scales associated with dynamic compression provide the opportunity to probe, in real time, physical and chemical changes as they occur. Such information is central to developing a mechanistic understanding of material phenomena.

Three representative examples, taken from the work by the author and his colleagues, will be discussed to demonstrate both the scientific achievements and challenges related to dynamic loading. These include structural changes in crystals, linking molecular dynamics to continuum response, and understanding spall. A new experimental paradigm will also be presented: use of a synchrotron facility to obtain x-ray diffraction measurements under shock wave compression.

The presence of large stress deviators in the presence of large confining stresses and the short time scales in dynamic loading experiments open up new opportunities for mechanics of materials. In particular, relating the continuum response to lower length scales represents an important challenge and an exciting opportunity. Future directions for research in linking multiple-length scales will be indicated.