Research Group Profile

Computational Solid Mechanics Group

Louisiana State University

Nonlocal Modeling of Materials

Problem

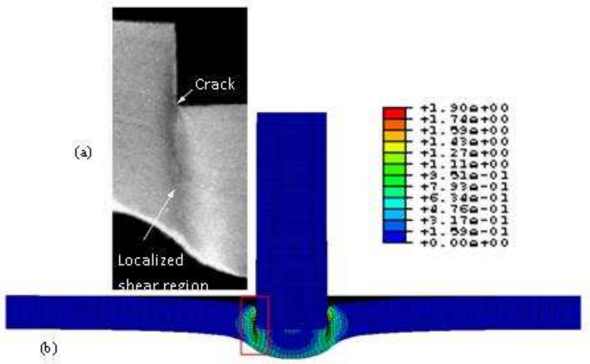
One of the key challenges in improving existing or developing new engineering materials with fine tailored mechanical performances is to link microstructure with macroscopic material behavior. While mean-field theories based on classical continuum approaches appropriately capture this link for elastic behavior, the development of a macroscopic model embedded with a micromechanics-based theory of inelasticity that could be used as an engineering theory for both the analysis and computer-aided design of materials, is still a challenging endevour. The main difficulty stems from the fact that the inelastic deformation which develops in materials, is not homogeneous. In contrast, it reveals fluctuations on various length scales, that cannot be captured within the classical framework of continuum mechanics. In turn, this heterogeneity plays a key role in determining the macroscopic properties of materials. All this motivates the development of a theory that is able to bridge the gap between conventional continuum theories and micromechanical theories.

Approach

Here we adopt the perspective that a nonlocal macroscopic continuum theory has the potential to capture the heterogeneity of inelastic deformation. With this focus in mind, we investigate the fundamental mechanisms responsible for the inelastic behavior of advanced engineering materials from nano to macro scales (e.g., plasticity, visco-plasticity, damage, friction, wear) within the framework of computational solid mechanics. This includes the development of mathematical models, numerical algorithms and software with the final aim of predicting the behavior of engineering materials using computer simulations.

Core Competencies

- **Nonlocal formulation of nano/micro material systems for predicting the inleastic behavior using computer simulations.**
- **Multiscale mechanical modeling of high speed contact stress problems.**
- **Computational approaches for solving boundary value problems.**
- **Nanoindentation for identification of mechanical properties and for characterization mechanisms responsible for plasticity in the material structure.**



Simulation of perforation of the target plate by a high-speed blunt projectile using proposed computational model showed that high speed impact damage lead to fracture due to global inelastic strains, bending and dishing at end of the plate.

This approach is key to answering some key questions such as: (i) the effect of grain size, interfaces, and number of grains on the yield strength and flow stress of thin film

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materials; (ii) optimal deposition parameters for achieving the desired microstructure; (iii) explore the strengthening deformation mechanisms due to their unique microstructure; and (iv) multiscale and physical-based theoretical and computational models to capture the observed mechanical response and scale-dependent characteristics.

Recent Findings

Our recent works reveal that introducing interface energy as an additional contribution to internal virtual power establishes a physical base for nonstandard boundary conditions as well as the description of the boundary layers in thin film structures. The decomposition of the state variables into energetic and dissipative components helps us understand the hardening and strengthenning mechanisms in nano/micro structured materials.

Impact

The research findings contribute to advancing the development of fundamental understanding of rate dependent behavior, damage evolution, friction and wear in nano/micro structured material investigations. Thanks to these findings, it becomes now possible to redesign, and redefine material choices for wide-range applications in aerospace industry, materials science, and mechanical, civil, polymer, and electrical engineering.

Current Research Team Members:

- Adam Lodyqowski (Ph.D. Candidate)
- Danial Faghihi (Ph.D. Candidate)
- Cheng Zhang. (Ph.D. Candidate)
- Navid Mozaffari (Ph.D. Candidate)
- Dr. Babur Deliktas (Research Associate)

Recent Graduates:

- Dr. Amin H. Almasri (Ph.D. 2008).
- Dr. Ziad N. Taqieddin (Ph.D. 2008).

Current Research Collaborations:

- Ultra high speed sliding between Steel and VascoMax steel at Ecole de' Nationale Institut der Mechanic, at Metz France
- Non-Local Coupling of Friction and damage in High Velocity Wear, Air force Institute of Technology, WPAFB
- Nonlocal modeling and parallel computations (Dr. Babur Deliktas, Turkey)
- Localizations in Metals and Composites due to High Impact Damage, Poznan University, Poland, Professor Tomasz Lodygowski.

Selected Publications

1. Voyiadjis, G.Z., Deliktas, B., 2009a. Formulation of strain gradient plasticity with interface energy in a consistent thermodynamic framework. *Int. J. Plasticity* 25 (10), 1997-2024.

2. Voyiadjis, G.Z., Deliktas, B., 2009b. Mechanics of strain gradient plasticity with particular reference to decomposition of the state variables into energetic and dissipative components. *Int. J. Engineering Science* 47 (11-12), 1405-1423.

3. Voyiadjis, G.Z., Almasri, A.H., 2009. Variable material length scale associated with nanoindentation experiments. *J.Engrg. Mech.*, ASCE 135(3), 139-148.

4. Voyiadjis, G.Z., Abu Al-Rub, R.K., 2007. Nonlocal gradient-dependent thermodynamics for modeling scale-dependent plasticity. *Int. J. Multiscale Computational Engineering* 5 (3-4), 295-323.

5. Abu Al-Rub, R.K., Voyiadjis, G.Z., 2005. A direct finite element implementation of the gradient-dependent theory. *Int. J. for Numer Meth in Engrg* 63 (4), 603-629.

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