MSE 612: Computational Plasticity and Micromechanics

Instructor: Dr. Yanfei Gao (ygao7@utk.edu)
Info: Fall 2015, 9:40-10:55am, Tue/Thu, 510 Ferris Hall

Objectives

Computational modeling and simulation methods will be introduced with applications in plasticity, fracture and fatigue, microstructural evolution, and material instability in engineering materials. Topics include the classic finite element method based on constitutive modeling, cohesive interface model, discrete defect method, and current research areas that are pertinent to the research efforts in UT and ORNL (such as shear banding behavior in metallic glass, neutron diffraction, etc.). The students will be provided with templates of user defined element and material subroutines for the use of ABAQUS, and will also be asked to do simple practices.

Textbook

You will be primarily provided with lecture notes and directed to related papers. A main reference and basis of this lecture is *Applied Mechanics of Solids*, by A.F. Bower, Taylor-Francis, 2009. (This book can also be accessed from http://solidmechanics.org). Please refer to this monograph if you are unclear with some discussions in this lecture. For background in materials science, particularly on microstructure, dislocations, creep, etc., you can refer to *Mechanical Metallurgy*, by G.E. Dieter, McGraw-Hill, 1986.

Content[1]

1. Constitutive Behavior
   (1) Elements of continuum mechanics
   (2) Continuum (phenomenological) plasticity
   (3) Thermodynamic basis
   (4) Applications in materials science and engineering
2. Finite Element Method
   (1) Finite element analysis (FEA) procedure
   (2) Principle of virtual work
   (3) Finite element method for linear elastic solids
   (4) Finite element method for plastic solids
   (5) Implementation procedure
   (6) Stress update algorithm
   (7) Practicing ABAQUS UMAT subroutine
3. Material Failure
   (1) Phenomenology of fracture and fatigue
   (2) A viewpoint at the crack tip
   (3) Modeling the crack tip process zone
   (4) Stress and strain based failure criteria
4. Crystal Plasticity
   (1) Deformation mechanisms in single crystal and polycrystals
   (2) Continuum crystal plasticity theory
   (3) Finite element simulations
   (4) Applications and future comments

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[1] If you have special research interests (that are related to this course) and prefer to have them covered in this course, we can discuss this possibility.

5. Material Instability
    (1) Geometric vs material instability
    (2) Hill-Hutchinson-Rice theory
    (3) Numerical simulations
    (4) Shear band angle analysis in metallic glasses
6. Microstructure-based simulations
    (1) Stress effects in phase transformation
    (2) Non-equilibrium thermodynamics
    (3) Cavitation in high temperature alloys
    (4) Thin film mechanics

<u>Homework: A practice of ABAQUS and UMAT (30%)</u>

Given:

- a boundary value problem
- a <u>U</u>ser defined <u>MAT</u>erial (UMAT) Subroutine on Mises plasticity

Perform:

- understand the format and usage of UMAT
- compare results using ABAQUS alone and using ABAQUS UMAT

Hand in 1-page writing:

- briefly explaining Mises plasticity and UMAT
- showing one plot of comparison

<u>Course Project – Step 1 (20%)</u>:

- Identify your own course project and give an in-class presentation on project background
- Grade from peer students (10%)
- My evaluation (10%)

<u>Course Project – Step 2 (50%)</u>:

- Final project presentation (20%)
    - grade from peer students (10%)
    - my evaluation (10%)
- Project report (4-page limit, 30%)

Additional Notes

- Homework is mainly a practice. As long as you do the calculation and show the comparison, you'll be rewarded fairly.
- Don't be too ambitious on your course project. What I want to see is a well defined topic and your effort on it.
- *Scientists must speak*: be sure to present what you clearly know, and be prepared to answer questions from non-experts.
- *Scientists must write*: a well written project report is highly desirable. Do not just pile up numerical results without illustration and explanation.