CE 8930 - 001 (Spring 2015)
Inelastic Materials - Modeling and Computation

INSTRUCTOR

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Office hours: Tuesdays, 2:00 – 4:00 pm; other time by appointment

CLASS TIME AND PLACE

11:00am - 12:15pm Tuesdays & Thursdays Lowry Hall 219

RECOMMENDED TEXTBOOKS

Lecture notes and handout will be posted on blackboard. The following books are highly recommended references:

[1]. Plasticity - Modeling and Computation, R.I. Borja, 2013.
[2]. Fundamentals of Continuum Mechanics, J. Rudnicki, 2014.
[3]. Computational Inelasticity, J.C. Simo and T.J.R. Hughes, 2008.
[4]. Nonlinear Solid Mechanics: A Continuum Approach for Engineering, G.A. Holzapfel, 2000.
[5]. Nonlinear Finite Elements for Continua and Structures, T. Belytschko, W.K. Liu and B. Moran, 2000.

COURSE DESCRIPTION

Many natural and engineered materials, such as geomaterials, metals and biomaterials, generally exhibit an irreversible (inelastic) deformation behavior such that when an applied load is removed only a fraction of the deformation is recovered. The mechanisms responsible for irreversible deformation vary from one material to another. Significant understanding can be gained from modeling and simulating irreversible deformation behavior of those materials, which requires appropriate material models to be developed and implemented.

In this course, we will (1) introduce the basic components of elasto-(visco) plastic constitutive models for capturing various inelastic material behavior; (2) develop the underpinning computational platform to implement constitutive models into nonlinear finite element codes; and (3) discuss the potential applications of inelastic material models. Selected material models that are of interest to various disciplines will be discussed in class. Equal emphasis will be placed on the theory behind various models and the implementation of these models into nonlinear finite element codes.

COURSE OBJECTIVES

By the end of this course, students will be able to develop an understanding for the basic ingredients involved in elasto-(visco) plastic constitutive models and be able to develop efficient and robust integration algorithms for advanced plasticity models to be used within the framework of nonlinear finite element procedures.

GRADING

Homework	70%
Final project	30%
Total	100%

TENTATIVE CLASS TOPICS

1. **Introduction**
   The big picture; structure of a nonlinear FEM program

2. **Vector and Tensor Review**

3. **Elastoplasticity in One Dimension**
   Key ingredients of 1D elastoplasticity problems; notion of isotropic and kinematic hardening; basic numerical solution procedures in 1D

4. **Inelastic Material Models I**
   Deviatoric (J2) plasticity; flow rule; isotropic, kinematic and combined hardening; plastic dissipation and thermodynamics principles

5. **Integration Algorithms**
   Return mapping; consistent tangent operator; introduction to general return mapping algorithms; implementation strategy

6. **Inelastic Material Models II**
   Selected inelastic material models (two- and three-invariant models; rate-dependent models; damage models)

7. **Selected Applications and Advanced Topics**
   Material instability; limitations of classical inelastic models; length scales; strain localization; viscoplastic regularization

CLASS ATTENDANCE AND POLICY

- Class attendance is extremely important of this course. Students are required to attend every lecture. If you miss more than three lectures without valid excuses, you will be dropped or receive incomplete grade for this course.
- In the event that the instructor is late for the lecture, you are free to leave after you have waited for 10 minutes.
- No Food or cellphone usage during class period.

EMAIL COMMUNICATIONS

- Please use your official Clemson email for communications regarding this course.
- The very first time you email me, please use your full name, not just first name to avoid confusion.
- Start your **email subject line with CE8930** is a good way to make sure your email won't be missed.

ACADEMIC INTEGRITY

As members of the Clemson University community, we have inherited Thomas Green Clemson's vision of this institution as a "high seminary of learning." Fundamental to this vision is a mutual commitment to truthfulness, honor, and responsibility, without which we cannot earn the trust and respect of others. Furthermore, we recognize that academic dishonesty detracts from the value of a Clemson degree. Therefore, we shall not tolerate lying, cheating, or

stealing in any form. When in the opinion of a faculty member, there is evidence that a student has committed an act of academic dishonesty, the faculty member shall make a formal written charge of academic dishonesty including a description of the misconduct, to the Dean of the Graduate School. At the same time, the faculty member may, but is not required to, inform each involved student privately of the nature of the alleged charge.

STUDENTS WITH DISABILITIES

Students with disabilities who need accommodations should make an appointment with Dr. Arlene Stewart, Director of Disability Services, to discuss specific needs within the first month of classes. Students should prevent a Faculty Accommodation Letter from Student Disability Services when they meet with instructors. Student Disability Services is located in Suite 239 Academic Success Building (656-6848; sds-l@clemson.edu). Please be aware that accommodations are not retroactive and new Faculty Accommodation Letters must be presented each semester.

CLEMSON UNIVERSITY'S TITLE IX POLICY

Clemson University's Title IX (Sexual Harassment) policy is located at
http://www.clemson.edu/campus-life/campus-services/access/harassment.html
Jerry Knighton serves as Clemson's Title IX coordinator.

IMPORTANT DATES

A copy of academic calendar with important dates is available at
http://www.registrar.clemson.edu/html/acad_cal.htm

FINAL REMARKS

Inelastic materials have extremely wide presences in many engineering disciplines. The ability to model and simulate behavior of inelastic materials will provide us new insights to understand and eventually predict their behavior. You are always welcome to discuss with me your suggestions or concerns that will make this class better. Good luck to all of you in this class!