

## **Inelastic materials**

**EGM 6671**

***Class Periods in Gainesville:*** Tuesday, 2nd and 3rd period; Thursday, 3rd period

***Location:*** Reversed Edge

***Academic Term:*** Spring 2022

### ***Instructor:***

Dr. Benoit Revil-Baudard

Office: 153 UF/REEF, Shalimar, FL 32579

Office hours: Tuesday 10:00 am to 12:00 pm CT

Phone: (850) 833-9350 ext. 241

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**Gainesville Campus Teaching Assistant:** no TA

**TA's Office:**

**Class Website:** <https://lss.at.ufl.edu>

Sign in to e-Learning in Canvas by clicking on "e-Learning in Canvas"

Login using your gatorlink username and password

***In Shalimar, class meets on Monday: 1.00 pm-4.00pm***

### ***Course Description***

Credits 3

### ***Course Pre-Requisites / Co-Requisites***

Completion of graduate course EGM 5533 "Applied elasticity and advanced mechanics of Solids" or permission of the instructor.

### ***Course objectives:***

The purpose of the course is to provide students with exposure to the theory of plasticity, for both single crystal and polycrystalline metallic materials. Upon completion, each student should have:

- Fundamental understanding of the theory of plasticity for isotropic and anisotropic metallic materials and the ability to apply this knowledge to model the non-linear behavior of metallic materials and processes
- Knowledge of the plastic properties of various materials used in structural applications and skills needed for development of new constitutive laws for new advanced alloys
- Knowledge of how the particularities of plastic deformation influence damage and fracture of structural metallic materials

### ***Course outcomes***

After a successful completion of this course, the student should:

- Show profound knowledge of the basic concepts of plasticity and damage mechanics and understand the capabilities and limitations of the different constitutive models introduced in the course
- Determine based on the results of mechanical tests the most appropriate material model to be used for a given application;
- Identify the material parameters associated with any given material model and prepare material input data for finite element modeling;
- Solve boundary value problems using the respective models;
- Master key techniques and concepts to be used for development of new models
- Have the ability to critically judge the content of technical papers and seminars.

## **Materials and Supply Fees**

### **Recommended Textbooks and Software**

One of the two books:

- Title : Plasticity of Metallic Materials: Modeling and Applications to Forming.
- .Authors: Cazacu, O., & Revil-Baudard, B
- Editor: Elsevier

Or

- Title : Plasticity-damage couplings: from single crystal to polycrystalline materials
- .Authors: Cazacu, O., Revil-Baudard, B., & Chandola, N
- Editor: Springer

Remarks:

- Lecture notes will be made available in the Canvas website after each lecture
- For Applications and examples, the Finite Elements software LS Dyna will be used. Student version of the software could be downloaded at <https://www.ansys.com/academic/students/ansys-ls-dyna-student>

### **Course description:**

- Review of concepts of continua, tensor analysis, stress and deformation tensors, balance and conservation laws and elasticity
- Mathematical framework of the theory of plasticity
- Modeling of plastic deformation of isotropic metallic materials
  - Classic isotropic yield criteria
  - Recent yield criteria for isotropic metallic materials displaying asymmetry between the strength in tension and compression (Cazacu and Barlat, 2004; Cazacu et al. 2006)
  - Applications
- Modeling geomaterials (Concrete and Soils)
- Modeling plastic deformation of single crystal
  - Concepts of crystallography
  - Mechanisms for plastic deformation of single crystals
  - Yield criteria for single crystals
- Modeling plastic deformation of textured polycrystalline materials and alloys
  - Symmetry requirements; Representation Theorems
  - Methodologies to extend isotropic yield criteria such as to account for anisotropy
  - Classic yield criteria for anisotropic metallic materials with cubic crystal structure: Hill (1948); Barlat et al (1991); Cazacu and Barlat (2001), Barlat et al (2006)
  - Application to steel and aluminum
  - Yield criteria for anisotropic metallic with hexagonal crystal structure: Cazacu and Barlat (2004); Cazacu et al (2006), Nixon et al (2010)
  - Applications to Magnesium, Titanium, Zirconium alloys.
- Role of plastic deformation on damage evolution in metallic materials: modeling the effect of plastic deformation on damage evolution in porous isotropic metallic materials
  - Models for porous materials with von Mises matrix: Gurson (1975), Cazacu et al (2012)
  - Models for porous materials with Tresca matrix: Cazacu et al (2013)
  - Models for porous materials with matrix displaying tension-compression asymmetry: criterion of Cazacu and Stewart (2009)
  - Models for porous materials anisotropic metals: Benzerga and Besson (2001), Stewart and Cazacu (2011)
- Applications to description of damage evolution in Aluminum and Titanium materials
- Finite element implementation of elastic plastic constitutive models
  - Integration algorithms and Applications

### Course Schedule

Week 1:	Introduction: History + Presentation of LS-Dyna ()
Week 2:	Recall on Calculus + Theory of Elasticity
Week 3:	Mathematical framework of the theory of plasticity
Week 4:	Plasticity and Finite Elements
Week 5-7:	Modeling of plastic deformation of isotropic metallic materials + Applications
Week 8	Modeling Geomaterials (Concrete and Soils)
Week 9-11:	Modeling plastic deformation of single crystal + Applications
Week 12-14:	Modeling plastic deformation of textured polycrystalline materials and alloys+ Applications
Week 15-16:	Role of plastic deformation on damage evolution in metallic materials: modeling the effect of plastic deformation on damage evolution in porous isotropic metallic materials

### Attendance Policy, Class Expectations, and Make-Up Policy

**Course web site:** A course web site is established thru UF/EDGE. Students will be expected to check it on a regular basis for up-to-date course information. This may include changes to the syllabus, homework assignment due dates, and exam schedules.

**Exams:** Two exams will be given during the semester. No final exam will be given.

*Tentative schedule of the exams: Exam1: February 22<sup>nd</sup> ; Exam 2 will be a mini project due for week 15 (April, 11<sup>th</sup> - 16<sup>th</sup>)*

No exams will be given prior to the scheduled dates and no makeup exams will be given.

**Homework:** Problems will be assigned on Tuesday and collected at the end of the following Tuesday class meeting. Late homework will not be accepted. However, hardship cases will be considered on an individual basis and only if the instructor has been contacted before the due date of the assignment.

Excused absences must be consistent with university policies in the Graduate Catalog (<https://catalog.ufl.edu/graduate/regulations>) and require appropriate documentation. Additional information can be found here: <https://catalog.ufl.edu/UGRD/academic-regulations/attendance-policies/>

### Evaluation of Grades

Assignment	Total Points	Percentage of Final Grade
Homework	100 each	25%
Exam 1	100	35%
Exam 2 : Project	100	40%
		100%

### Grading Policy

Percent	Grade	Grade Points
93.4 - 100	A	4.00
90.0 - 93.3	A-	3.67
86.7 - 89.9	B+	3.33
83.4 - 86.6	B	3.00
80.0 - 83.3	B-	2.67
76.7 - 79.9	C+	2.33
73.4 - 76.6	C	2.00
70.0 - 73.3	C-	1.67
66.7 - 69.9	D+	1.33
63.4 - 66.6	D	1.00
60.0 - 63.3	D-	0.67
0 - 59.9	E	0.00

More information on UF grading policy may be found at:

<http://gradcatalog.ufl.edu/content.php?catoid=10&navoid=2020#grades>

### ***Students Requiring Accommodations***

Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center by visiting <https://disability.ufl.edu/students/get-started/>. It is important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

### ***Course Evaluation***

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at <https://gatorevals.ua.ufl.edu/students/>. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via <https://ufl.bluera.com/ufl/>. Summaries of course evaluation results are available to students at <https://gatorevals.ua.ufl.edu/public-results/>.

### ***In-Class Recording***

Students are allowed to record video or audio of class lectures. However, the purposes for which these recordings may be used are strictly controlled. The only allowable purposes are (1) for personal educational use, (2) in connection with a complaint to the university, or (3) as evidence in, or in preparation for, a criminal or civil proceeding. All other purposes are prohibited. Specifically, students may not publish recorded lectures without the written consent of the instructor.

A “class lecture” is an educational presentation intended to inform or teach enrolled students about a particular subject, including any instructor-led discussions that form part of the presentation, and delivered by any instructor hired or appointed by the University, or by a guest instructor, as part of a University of Florida course. A class lecture does not include lab sessions, student presentations, clinical presentations such as patient history, academic exercises involving solely student participation, assessments (quizzes, tests, exams), field trips, private conversations between students in the class or between a student and the faculty or lecturer during a class session.

Publication without permission of the instructor is prohibited. To “publish” means to share, transmit, circulate, distribute, or provide access to a recording, regardless of format or medium, to another person (or persons), including but not limited to another student within the same class section. Additionally, a recording, or transcript of a recording, is considered published if it is posted on or uploaded to, in whole or in part, any media platform, including but not limited to social media, book, magazine, newspaper, leaflet, or third party note/tutoring services. A student who publishes a recording without written consent may be subject to a civil cause of action instituted by a person injured by the publication and/or discipline under UF Regulation 4.040 Student Honor Code and Student Conduct Code.

### ***University Honesty Policy***

UF students are bound by The Honor Pledge which states, “We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: “On my honor, I have neither given nor received unauthorized aid in doing this assignment.” The Conduct Code (<https://sccr.dso.ufl.edu/process/student-conduct-code/>) specifies a number of behaviors that are in violation of this code and the possible sanctions. If you have any questions or concerns, please consult with the instructor or TAs in this class.

### ***Commitment to a Safe and Inclusive Learning Environment***

The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. It is expected that every

person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

- Your academic advisor or Graduate Program Coordinator
- Jennifer Nappo, Director of Human Resources, 352-392-0904, [jpennacc@ufl.edu](mailto:jpennacc@ufl.edu)
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, [taylor@eng.ufl.edu](mailto:taylor@eng.ufl.edu)
- Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, [nishida@eng.ufl.edu](mailto:nishida@eng.ufl.edu)

### ***Software Use***

All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

### ***Student Privacy***

There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: <https://registrar.ufl.edu/ferpa.html>

### ***Campus Resources:***

#### ***Health and Wellness***

##### **U Matter, We Care:**

Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact [umatter@ufl.edu](mailto:umatter@ufl.edu) so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

**Counseling and Wellness Center:** <https://counseling.ufl.edu>, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

##### **Sexual Discrimination, Harassment, Assault, or Violence**

If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the **Office of Title IX Compliance**, located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, [title-ix@ufl.edu](mailto:title-ix@ufl.edu)

##### **Sexual Assault Recovery Services (SARS)**

Student Health Care Center, 392-1161.

**University Police Department** at 392-1111 (or 9-1-1 for emergencies), or <http://www.police.ufl.edu/>.

#### ***Academic Resources***

**E-learning technical support**, 352-392-4357 (select option 2) or e-mail to [Learning-support@ufl.edu](mailto:Learning-support@ufl.edu).  
<https://lss.at.ufl.edu/help.shtml>.

**Career Resource Center**, Reitz Union, 392-1601. Career assistance and counseling; <https://career.ufl.edu>.

**Library Support**, <http://cms.uflib.ufl.edu/ask>. Various ways to receive assistance with respect to using the libraries or finding resources.

**Teaching Center**, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring.  
<https://teachingcenter.ufl.edu/>.

**Writing Studio, 302 Tigert Hall**, 846-1138. Help brainstorming, formatting, and writing papers.  
<https://writing.ufl.edu/writing-studio/>.

**Student Complaints Campus**: <https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/>; <https://care.dso.ufl.edu>.

**On-Line Students Complaints**: <http://www.distance.ufl.edu/student-complaint-process>.