Course Syllabus

VM611

Constitutive Modeling and Constitutive Updates of Solids

Summer 2021

Course Description:

This course introduces the general principles of constitutive modeling of solids, and algorithms for the constitutive updates of some of such models. The first part of the course focuses on homogeneous material modeling. First, the general thermodynamic and objectivity concerns of modeling are presented, and then hyperelastic constitutive models are elaborated in the context of large deformations, of which anisotropic linear elasticity will be treated as a special case. Then models with internal variables such as plasticity, viscoplasticity, and damage will be discussed, together with the relevant updating algorithms such as return mapping The second part of the course is on the modeling of heterogeneous materials, with a focus on methods to obtain their effective properties, from analytic methods to asymptotic homogenization.

Instructor:

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Office hour: The problem sessions (Tuesdays 14:00—15:40, CRQ 108) also serve as office hours.

COURSE OBJECTIVES:

After learning the course, students will be able to comprehend the basic requirements of constitutive relations, verify reversible and irreversible hyperelastic constitutive models, and derive relevant quantities such as stress and the elasticity tensor. Students will also be able to formulate the numerical problem to obtain effective properties of heterogeneous materials.

COURSE OUTCOMES:

Students should be able to:

1. Given the free energy expression for an isotropic hyperelastic material, derive the stress and elasticity tensor.
2. Given the free energy expression for an anisotropic hyperelastic material, derive the stress and elasticity tensor.
3. Given the free energy expression for a hyperelastic material with internal variables, derive the stress and elasticity tensor, and dissipation.
4. Given the structure and constituent properties of a heterogeneous material, formulate the numerical problem to get the effective properties.

Textbook (Author, Book Title, Publisher, Publication Year, ISBN)**:**

G. Holzapfel, Nonlinear Solid Mechanics: A Continuum Approach for Engineering, Wiley, 2000, ISBN 0 471 82304 X (ppc) 0 471 82319 8 (pbk)

J.C. Simo and T.J.R. Hughes, Computational Inelasticity, Springer, 1998, ISBN 0-387-97520-9

Kezhi Huang, Yonggang Huang, Constitutive Relations of Solids (in Chinese), Tsinghua University Press, 1999, ISBN 9787302036630

Li Liao, Xiaoning Liu Constitutive Foundation of Solid (in Chinese), Beijing Institute of Technology Press, 2017, ISBN 9787568250023

Course Prerequisites:

VM513 (Continuum Mechanics) or VM512 (Elasticity) or VM505 (Finite Element Methods) or VM518 (Composite Mechanics)

Course Website:

On canvas.

Grading Policy (Assignments %, Project, Exams, etc.)**:**

- Attendance in Problem Sessions (10%)
- Midterm Exam (30%)
- Term Project 1 (20%)

- Term Project 2 (20%)
- Term Project 3 (20%)

Honor Code Policy:

JI Honor Code needs be abided by: http://umji.sjtu.edu.cn/academics/academic -integrity/honor-code/

Teaching Schedule:

Week	NO.	lectures and Exams	Comments
1	1	General consideration of constitutive modeling	[H] Ch5
	2	Objectivity	[H] Ch5
2	3	Hyperelastic materials	[H] Ch6
	4	Elasticity tensors	[H] Ch6
3	5	Incompressible and compressible isotropic materials	[H] Ch6
	6	Some forms of strain energy functions	[H] Ch6
4	7	Transversely isotropic materials	[H] Ch6
	8	Composites with two families of fibers	[H] Ch6
5	9	Anisotropic linear elasticity	Nye
	10	Consideration of crystallography	Nye
6	11	Constitutive models with internal variables	[H] Ch6
	12	Damage	[H] Ch6
7	13	Phase field approach to fracture	
	14	Phase field approach to fracture	
8	15	Rate-independent plasticity	[SH] Ch1-2
	16	Rate-independent plasticity	[SH] Ch1-2
9	17	Return mapping algorithm	[SH] Ch1,3
	18	Return mapping algorithm	[SH] Ch1,3
10	19	Viscoplasticity and return mapping algorithm	[SH] Ch1-3
	20	Viscoplasticity and return mapping algorithm	[SH] Ch1-3
11	21	Composites	
	22	Representative volume. Hill-Mandel condition	
12	23	Asymptotic homogenization	
	24	Asymptotic homogenization	
13	25	Final Exam	
	26		