Chalmers University of Technology **2019-10-21 _ draft**
Department of Industrial and Materials Science

TME250 Finite Element Method - Solids

7.5 credit points,
Quarter 2, fall semester 2019

Instructors
Fredrik Larsson, ph. 772 1979, fredrik.larsson@chalmers.se
Ralf Jänicke, ph. 772 6397, ralf.janicke@chalmers.se
Fredrik Ekre, ph. 772 1227, fredrik.ekre@chalmers.se

General purpose and contents

The aim is to provide the student with further understanding of the nature of the Finite Element Method (FEM), in particular its approximate character, and to provide extended skill in applying FEM to engineering problems related to solid mechanics. Hence, the course builds on knowledge acquired in continuum mechanics (mechanics of solid bodies), material modeling and the application of FEM to basic problems. These topics are covered in the courses Mechanics of Solids TME235, Material Mechanics MHA042 and TME245 Finite Element Method – Structures. Computer assignments play a key role as the means of implementing and assessing models and algorithms.

Approximately 18 lectures will comprise the following topics:
- Linear elasticity: Some fundamentals
- Linear elasticity: Mixed methods, in particular for the incompressible limit
- Nonlinear elasticity: Finite deformation theory
- Contact mechanics
- Multifield/coupled problems: thermomechanics
- Linear elasticity: Error analysis and adaptive methods

Course web page

All course information, including handed out material and the updated schedule will be available on the course webpage on CANVAS. Add a bookmark!

Organization of lectures and lab classes

The course comprises lectures in accordance with the schedule available on the course web page. In addition, computer rooms are booked for the course for 4 hours per week. Each of the four computer assignment will be introduced in the computer classes according to the schedule.

Course work and examination

The main course work consists of four computer assignments (CA1-CA4) involving FE-computation using Matlab (CALFEM) and a final written exam.

The Calfem package can be downloaded from
http://sourceforge.net/projects/calfem/

The topics of the CA's are as follows:

- CA1: Incompressible elasticity (2 credit points)
- CA2: Contact mechanics (2 credit points)
- CA3: Finite elasticity (3 credit points)
- CA4: Error-control and adaptivity for linear elasticity (2 credit points)

An informal written report for each assignment must be submitted before the deadline given in the schedule. The assignments are graded and will then give maximum credit points as indicated above. Altogether, **9 credit points** can thus be obtained towards the final grade, see below. These points will remain valid until the course is given next time.

The final written exam is based on quizzes and problems that will accompany the lectures and will be put on the course homepage during the course. No aids are permitted during the final written exam. The exam comprises questions/problems of theoretical character. Altogether, **9 points** can thus be obtained towards the final grade, see below.

Grades are awarded as follows:

Collected credit points	Chalmers grade
0-9	U
10-12	3
13-15	4
16-18	5

To complete the course, it is thus **necessary to participate in computer assignments and complete the final exam**.

Course evaluation

A continuous evaluation will be held during and after the course consisting of three meetings: one introductory meeting during the first week, a mid-course meeting in the fourth week and a final evaluation after the course. A group of students are chosen at the first lecture to represent the class at the meetings. The goal of the mid-course meeting is to assess the current status of the course while the final meeting aims at developing the course for next year. **We greatly appreciate your feedback!** In-between the written exam and the final evaluation meeting, a questionnaire will be sent out to all course participants.

Literature

[1] M. Ekh, R. Jänicke, F. Larsson and K. Runesson, The Finite Element Method – Solid Mechanics. Department of Industrial and Materials Science, Chalmers University of Technology, 2018. (in preparation). **Selected chapters**.[1]
[2] N.S. Ottosen and H. Peterson. *Introduction to the finite element method.* Prentice –Hall, New York 1992.
[3] Fredrik Larsson. *Nonlinear finite element analysis – A short introduction*. Dept. of Applied Mechanics, Chalmers, 2010. [1]
[4] P-E. Austrell, O. Dahlblom, J. Lindemann, A. Olsson, K-G. Olsson, K. Persson, H. Petersson, M. Ristinmaa, G. Sandberg and P-A. Wernberg, *CALFEM, A Finite element toolbox to MATLAB, Version 3.4.* Dept. of Structural Mechanics and Solid Mechanics, Lund 2004. [2]
[5] Kenneth Runesson, Paul Steinmann, Magnus Ekh and Andreas Menzel , Tensor Calculus Toolbox, Excerpt from Constitutive Modeling of Engineering Materials –Theory and Computation, Chalmers University of Technology, 2011.[1]

[1] The pertinent chapters will be available on the course homepage (CANVAS) for individiual downloading. Hence there is no cost other than printing paper.
[2] Available for downloading in electronic format at
`http://www.solid.lth.se/fileadmin/hallfasthetslara/utbildning/kurser/FHL064_FEM/calfem34.pdf`

Course Schedule

W1						
Mon, 4/11	10^{00}-11^{45}	ML14	Lecture 1	Course Intro. Elasticity	FL, RJ	[1], Ch3
Wed, 6/11	10^{00}-11^{45}	ML14	Lecture 2	Linear elasticity	FL	[1], Ch3
	13^{15}-15^{00}	ML14	Lecture 3	Linear elasticity	FL	[1], Ch3
	15^{15}-17^{00}	MT0, MT9	Exercise	*Hand-out CA1*	FE	
W2						
Mon, 11/11	08^{00}-09^{45}	ML14	Lecture 4	Linear elasticity	FL	[1], Ch3
	10^{00}-11^{45}	MT0, MT9	Exercise		FE	
Wed, 13/11	10^{00}-11^{45}	ML14	Lecture 5	Linear elasticity	FL	[1], Ch3
	13^{15}-15^{00}	ML14	Lecture 6	Non-linear elasticity	FL	[1], Ch4
	15^{15}-17^{00}	MT0, MT9	Exercise		FE	
W3						
Mon, 18/11	08^{00}-09^{45}	ML14	Lecture 7	Contact problems	RJ	[1], Ch10
	10^{00}-11^{45}	MT0, MT9	Exercise		FE	
Wed, 20/11	10^{00}-11^{45}	ML14	Lecture 8	Contact problems	RJ	[1], Ch10
	13^{15}-15^{00}	ML14	Lecture 9	Contact problems	RJ	[1], Ch10
	15^{15}-17^{00}	MT0, MT9	Exercise	*Hand-out CA2*	FE	
Fri, 22/11	**17^{00}**			**Hand-in CA1**		
W4						
Mon, 25/11	08^{00}-09^{45}	ML14	Lecture 10	Non-linear elasticity, finite deformations	FL	[1], Ch5
	10^{00}-11^{45}	MT0, MT9	Exercise		FE	
Wed, 27/11	10^{00}-11^{45}	ML14	Lecture 11	Non-linear elasticity, finite deformations	FL	[1], Ch5
	13^{15}-15^{00}	ML14	Lecture 12	Non-linear elasticity, finite deformations	FL	[1], Ch5
	15^{15}-17^{00}	MT0, MT9	Exercise	*Hand-out CA3*	FE	
W5						
Mon, 2/12	08^{00}-09^{45}	ML14	Lecture 13	Non-linear elasticity, finite deformations	FL	[1], Ch5
	10^{00}-11^{45}	MT0, MT9	Exercise		FE	[1], Ch10
Wed, 4/12	10^{00}-11^{45}	ML14	Lecture 14	Coupled problems:Thermoelasticity	RJ	[1], Ch12
	13^{15}-15^{00}	ML14	Lecture 15	Error analysis	FL	[1], Ch15
	15^{15}-17^{00}	MT0, MT9	Exercise		FE	
Fri, 6/12	**17^{00}**			**Hand-in CA2**		
W6						
Mon 9/12	08^{00}-09^{45}	ML14	Lecture 16	Error analysis	FL	[1], Ch15
	10^{00}-11^{45}	MT0, MT9	Exercise		FE	
Wed, 11/12	10^{00}-11^{45}	ML14	Lecture 17	Error analysis	FL	[1], Ch15
	13^{15}-15^{00}	ML14	Lecture 18	Error analysis	FL	[1], Ch15
	15^{15}-17^{00}	MT0, MT9	Exercise	*Hand-out CA4*	FE	
Fri, 13/12	**17^{00}**			**Hand-in CA3**		
Week 7						
Mon, 16/12	08^{00}-09^{45}	ML14	Lecture 19	Error analysis	FL	[1], Ch15
	10^{00}-11^{45}	MT0, MT9	Exercise		FE	
Wed, 18/12	11^{00}-11^{45}	ML14	Lecture 20	Course summary - Course review	FL, RJ	
	13^{15}-15^{00}	ML14	Lecture 21	Course summary - Old exam + Q&A	FL, RJ	
	15^{15}-17^{00}	MT0, MT9	Exercise		FE	
Fri, 10/1 (2020)	**17^{00}**			**Hand-in CA4**		
Sat, 18/1 (2020)	**14^{00}-18^{00}**			**Written exam**		
Wed, 8/4 (2020)	**14^{00}-18^{00}**			**Re-sit exam**		
Wed, 19/8 (2020)	**14^{00}-18^{00}**			**Re-sit exam**		

Literature

[1] M Ekh, R. Jänicke, F. Larsson and K. Runesson, The Finite Element Method – Solid Mechanics. Dept. of Industrial and Materials Science, Chalmers, 2018.

Teachers

RJ = Ralf Jänicke
FL = Fredrik Larsson
FE = Fredrik Ekre