Chalmers University of Technology **2021-10-31**
Department of Industrial and Materials Science

TME250 Finite Element Method - Solids

7.5 credit points,
Quarter 2, fall semester 2021

Instructors
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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
- Non-linear elasticity: Small strain setting
- Contact mechanics
- Nonlinear elasticity: Finite deformation theory
- 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, 4 hours per week are schedule for computer classes. Each of the four computer assignments 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 comprises questions/problems of theoretical character. Altogether, **9 points** can thus be obtained towards the final grade, see below. The exam will be an open book exam, i.e., all aids (notes, books, print-outs, etc.) are allowed. The only restriction is that electronic equipment with communication abilities (cell-phones, computers etc.) are not allowed. Study questions accompanying the lectures will outline the possible topics for exam questions.

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**.

Changes from last year's edition of the course

After the restrictions related to the Covid-19 pandemic have been lifted, the course will be offered onsite this year, both lectures and computer classes.

Since previous year, the final exam is open-book (i.e. all aids permitted). This format will be kept this year. Hopefully, the final exam can be held on-site in Chalmers facilities. However, the format of the exam will not be affected in case the exam has to go online due to new restrictions.

A section on the arc-length method for solving strongly non-linear problems has been introduced in conjunction with the finite deformation elasticity part of the course. Consequently, the focus on general mixed formulations for linear elasticity has been reduced.

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 will be chosen during the first lectures 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, 2021. (in preparation). **Selected chapters**.[1]

[2] F. Larsson. *A note on the arc-length method,* Chalmers University of Technology, 2021. [1]

[3] N.S. Ottosen and H. Peterson. *Introduction to the finite element method.* Prentice –Hall, New York 1992.

[4] Fredrik Larsson. *Nonlinear finite element analysis – A short introduction*. Dept. of Applied Mechanics, Chalmers, 2010. [1]

[5] 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]

[6] 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`