SE2860: FEM modelling (8 hp), Autumn 2016

1. General information, intended learning outcomes & prerequisites

General information

The finite element method (FEM) is a powerful tool to solve PDE problems in engineering. Efficient use of FEM requires that the modelling of the physical phenomenon, or phenomena, of interest is carried out in an appropriate way. This course focuses on the modelling aspects of solving problems with the finite element method. Most of the effort will be spent on structural mechanical problems, where the deformation is due to non-trivial loads that may depend on the solution of problems from other fields of physics. For instance, if the deformation in a structure is driven by a heat flow, a heat transfer problem must be solved in addition to the structural problem. This can be done in a separate step or in a fully coupled manner. As another example, consider a fluid that interacts with a solid in such a way that the deformation of the solid affects the flow of the fluid which in turn may affect the deformation of the solid. A problem of this kind is often called a *multiphysics* problem (even though they are intra physics problems). The main objective of the course is to expand and improve the participants' abilities and skills in technical modelling of complex engineering multiphysics problems by use of FEM.

The course consists of a series of lectures, computer labs and tutorials, which will give the theoretical background to physics phenomena coupled to structural mechanics problems as well as practical modelling aspects. However, most time will be spent on four simulation exercises, which will give the participants comprehensive training in how to solve a multiphysics problem related to structural mechanics. The course discusses the usage of generally available FEM software packages, where the students primarily will use one: Comsol Multiphysics. One lecture will be used to introduce Comsol and another will be devoted to techniques on how to solve nonlinear and time dependent process with Comsol.

Intended learning outcomes

After the course the student should be able to:

- Identify the physical phenomena that need to be considered in order to solve a specific engineering problem.
- Formulate an appropriate discretized geometrical model that can be solved by FEM.
- Choose a material model, or models, that capture the key features in the application.
- Formulate relevant boundary conditions for a given multiphyics problem.
- Analyse the outcome of the FEM simulation.
- Describe and present the engineering problem that has been analysed, its mathematical formulation, the FEM model used to solve the problem and the results in a technical report.

Prerequisites

The student should have knowledge corresponding to a first course in the finite element method, i.e. have a firm understanding of the theoretical basis of FEM, and some experience from solving problems with a FEM program. The student is also expected to have a good background in solid mechanics. Some knowledge in heat transfer and fluid mechanics is also helpful.

2. Teachers and course home page

Jonas Faleskog (KTH Solid Mechanics), lectures and course responsible, faleskog@kth.se.
Carl-Magnus Everitt (KTH Solid Mechanics), workshops, computer labs, tutorials.
Magnus Boåsen (KTH Solid Mechanics), workshops, computer labs, tutorials.
Anders Eriksson (KTH Mechanics), general resource.
Mattias Unosson (Truestress AB), guest lecture.
Course home page (continuously updated): **https://www.kth.se/social/course/SE2860**

3. Literature

The course is based on in-house teaching material (as powerpoint presentation handouts, which will be distributed through the course web page, see above. Reference literature of interest is R. D. Cooks, D. S. Malkus, M. E. Plesha & R. J. Witt, Concepts and Applications of Finite Element Analysis, 4th Ed., Wiley, New York, 2002.

4. Course requirements, examination and grading

To pass the course, it is required to pass and be approved on the two course modules: *simulation exercises* (ÖVN1, 3 hp) and *project assignment* (PRO1, 5 hp). The grade (A-E) is based on the performance on in these two modules. A total of 100 points can be obtained in the two modules, where the simulation exercises can give up to 60 points and the project assignment can give up to 40 points. The grades are based on the points earned as follows:

Grade	Point interval
A	85-100
B	74-84
C	63-73
D	52-62
E	41-51
F	≤40

Simulation exercises, ÖVN1 (3 credits)

The simulation exercises have a key role for the learning in the course. A set of four simulation exercises (SE) should be solved and presented in a written report to be handed in. Students should work in groups of two or in exceptional cases in groups of three students. The SE:s are of rather different types and covers the whole process of simulation, starting from identifying the physical phenomenon or phenomena, choosing a suitable mathematical model, discretization into a FEM-model and solving it, and finally, interpretation of results including a check of relevance. However, a first and compulsory step in each simulation exercise is to derive a simple analytical model that captures the essence of the problem to be modelled. In this step, the physical phenomena involved should also be identified.

Prior to the deadline of each simulation exercise there will be several workshops where the students will get training in solving relevant problems, e.g. by a number of tutorials. Each SE is divided into tasks with increasing level of difficulty. If correctly solved and adequately described in the report, the first level gives 7 points, the second level gives additional 5 points and the last level gives additional 3 points. Thus, a fully solved simulation exercise, satisfactorily presented in a written report gives in total 15 points.

To limit the extent of a report, no more than 2500 words may be used, without any restriction of the number of included figures. However, every included figure must be described and referred to in the text. The simulation exercises should be submitted electronically as a pdf-file to the course responsible teacher on email-address: faleskog@kth.se, no later than 24:00 on the day of deadline to avoid late delivery deduction. Reports handed in after the deadline will suffer a deduction of 5 points for every initiated week of delay.

Project assignment, PRO1 (5 credits)
A realistic problem should be treated in the project and solved by FEM. The problem can be freely chosen: from another course, from an industrial connection, or from a hobby activity. The physical modeling, the numerical simulations and the interpretation will be considered in the grading. The project is mandatory, but can be performed on two different ambition levels. The lower level consists of a 2 page (no more, no less) description of an interesting scientific or technical problem, where FEM simulations can be relevant and useful. The expected challenges in the modelling are the main content of the report, and must be expressly discussed. For this level a maximum of 15 points can be obtained.

At the higher level, relevant simulations must be performed (with any suitable software). The report should contain a short description of the physical phenomenon or phenomena that have been considered, the mathematical modelling, the choice of FEM model (geometry and boundary conditions and if necessary initial conditions) and why it is chosen, interpretation of results including a check of relevance. Inclusion of a simple mathematical model is presented that gives a qualitatively correct answer is desired. Also, the students are encouraged to create a so called “Comsol App”, which can be used to study the influence of a limited set of key parameters on the solution. The report should be written by using at the most 4000 words, with no restriction of the number of included figures, but they must be described and referred to in the text. For this level a maximum of 40 points can be obtained.

All student groups should present their project idea by use of 2 to 3 power point slides during a 5 minutes presentation at the last lecture on Thursday, December 15. Failure to do so reduces the available points on the project assignment by 5. The deadline of the project is at 24:00 on the 31st of January, 2017. Reports handed in after the deadline will suffer a deduction of 5 points for every initiated week of delay.

5. Detailed plan for lectures and workshops

The teaching consists of lectures (L) and workshops (WS). The lectures will be held in lecture halls. The workshops will be held in computer rooms (WS-CL) Nils, Glader or Christopher, or in the seminar room (WS-EX) of the department of solid mechanics, Teknikringen 8D, 2nd floor. Workshops held in computer rooms will be devoted to solving tutorials as a prepatory step for the each of the simulation exercise. Workshops held in the seminar room will be used to work on the simulation exercises and students are recommended to bring their own laptop computer to work on. The lectures will be given by Jonas Faleskog, except Lecture 10, which is a guest lecture on industrial applications given by Mattias Unosson. All workshops will be organized by Carl-Magnus Everitt and Magnus Boåsen.

Detailed schedule

Week	Date	Time, Room	Class, Topic
44	Tue 1/11	15-18, L52	L1: Introduction, repetition of FEM (structural mechanics, heat conduction), introduction to multiphysics.
	Thu 3/11	9-12, K1	L2: Introduction Comsol (by Comsol).
	Fri 4/11	9-12, Nils	WS-CL: Tutorials preparing for SE1.
45	Tue 8/11	14-17, Q31	L3: Aspects of modelling; Material modelling.
	Thu 10/11	9-12, V34	L4: Cont. Material modelling, Time dependent processes.
	Fri 11/11	8-10, SHLF	WS-EX: Work on SE1
	Fri 11/11	24:00	**Deadline SE1**
46	Tue 15/11	15-18, L52	L5: Solution techniques and solvers in Comsol (by Comsol).
	Thu 17/11	9-12, Nils	WS-CL: Tutorials preparing for SE2.
	Fri 18/11	10-12, SHLF	WS-EX: Work on SE2.
47	Tue 22/11	15-18, L51	L6: Time dependent problems
	Thu 24/11	9-12, Glader	WS-CL: Work on SE2
	Thu 24/11	24:00	**Deadline SE2**
	Fri 25/11	9-12, E3	L7: Fluid structure interaction.
48	Tue 29/11	15-18, Christopher	WS-CL: Tutorials preparing for SE3
	Thu 1/12	9-12, L52	L8: Fluid structure interaction
	Fri 2/12	8-10, SHLF	WS-EX: Work on SE3
49	Mon 5/12	24:00	**Deadline SE3**
	Tue 6/12	13-16, Q34	L9: Failure phenomena.
	Fri 9/12	9-12, Nils	WS-CL: Tutorials preparing for SE4
50	Mon 12/12	24:00	**Deadline SE4**
	Tue 13/12	15-18, L52	L10: Guest lecture by Mattias Unosson.
	Thu 15/12	9-12, B2	L11: Seminar, every group presents their project idea.
	Fri 16/12	9-12, Bure	WS-CL: Initial work on the project