Bridging the Complexity Gap in Modern Engineering Education with COMSOL Multiphysics® Software

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Abstract

Today multiphysics simulations play an important role in research and development in almost all disciplines. Therefore it is necessary to teach them at the universities to provide the industry with well-trained graduate students. Practically this means, that students should learn the handling of commercial multiphysics tools in order to set up reliable models. However, it is more important to train them how to interpret the numerical results comprehensively, i.e. qualifying them to draw the right conclusions for model optimizations and to estimate the influence of the used approximations on the obtained results. Several condition must be met: The students need a broad understanding of the underlying mathematical and numerical methods, a "feeling" for the physics, and an easy-to-use tool to set up example models.

Here, we demonstrate how COMSOL Multiphysics® can be used in different phases of an engineering study program. A problem in the early phase of every engineering study program is the necessary but for most students "scary" mathematics education. Moreover, knowledge in vector analysis, partial differential equations, variational calculations, and numerical methods is usually missing. Here, COMSOL Multiphysics® serves as an excellent tool to teach complex mathematics and demonstrate the practical use of simulations. The handling of the software is easy to learn and the student experiences quite soon the feeling of success.

Furthermore, we use COMSOL Multiphysics® for teaching numerical methods and specifically the finite element method in a later phase of the study program where the students own a more comprehensive mathematical background. In our lectures about the finite element method we use a simple example problem, which can be solved analytically. By comparing numerical and analytical results step by step even complex methodical and physical concepts are much easier to comprehend by the students. We use a one-dimensional heat transfer problem with an internal heat source (e.g. from Joule heating), a Neumann boundary condition (heat flux) and a Dirichlet boundary condition (fixed temperature). This way, the meaning and influence of different boundary conditions on the analytical as well as the numerical result can be demonstrated. In addition, the influence of the input parameters is discussed so that the students get a solid understanding of the underlying physical processes. Model extensions as well as model improvements by using a finer discretization or higher order shape functions can be demonstrated in the GUI of COMSOL Multiphysics® in a very comfortable way. On the basis of this simple one-dimensional model the generalization to two or three dimensions is straight forward and easy comprehensible so that the students finally are enabled to set up rather complicated multiphysics

models during the accompanying practical lab course.