

# Teaching Simulation Methods with COMSOL Multiphysics®

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## Abstract

### Introduction

Simulation of components and processes becomes more and more important in industry; therefore it is necessary to train young engineers how to apply simulation software in a sensible way. We established two consecutive courses for graduate students in which we decided to focus on COMSOL Multiphysics®, because it is widely utilized in industry and very intuitive to handle. To achieve an excellent education for the students, different didactical methods were developed.

There is a lot of literature on the use of COMSOL Multiphysics® in education available, but these papers basically focus on the application of COMSOL Multiphysics® to understand the underlying physical, biological or chemical phenomena. The educational aspects and the building of the simulations are not the main objective. With the presentation of our Courses "Simulation Methods" and "Simulation and Optimization in Virtual Engineering" we want to close the gap.

### Use of COMSOL Multiphysics®

The main philosophy of the first course "Simulation Methods" is to combine theory and praxis, therefore an educational concept with respect to the revised Bloom Taxonomy [1] was worked out. During the course we increased the level of difficulty in the COMSOL Multiphysics® examples and left out more and more details in the descriptions. Finally the students were able to work autonomous with the software. To train "soft skills", we introduced project work as final examination. The students could select between predefined topics and their own project ideas.

In the advanced course "Simulations and Optimization in Virtual Engineering" the students learned to analyze and to identify optimization potential and to formulate these problems in mathematical terms. Because these problems are very complex (e.g. multicriterial optimization problems with different optimization goals), this course is more challenging. The students learn how to couple COMSOL Multiphysics® Simulations with different optimization methods. Therefore the COMSOL Optimization Module as well as the LiveLink™ for MATLAB® was used.

### Results

#### Simulation Methods

Figure 1 shows the result of an exemplary students' project with title "Comparison of different

wingtip designs". The students implemented several simulations, and investigated the performance of different designs. See Figure 1: Result of students' project: Comparison of different wingtip designs.

### Simulation and Optimization in Virtual Engineering

One project was to optimize the paint drying of a car in an infrared oven. This project was given to the students in the last lectures. See Figure 2: Simplified 2D situation and scalarized objective function.

### Conclusion

The final evaluations revealed that the students learned during the course and their projects to work independently, without instructions and supervising. They learned to understand practical problems, to implement them in COMSOL Multiphysics®, to analyze the results and after all to create a report with final presentation.

## Reference

[1] D.R. Krathwohl A Revision of Bloom's Taxonomy – An Overview, Theory Into Practice, Vol. 41, No. 4 (2002)

## Figures used in the abstract

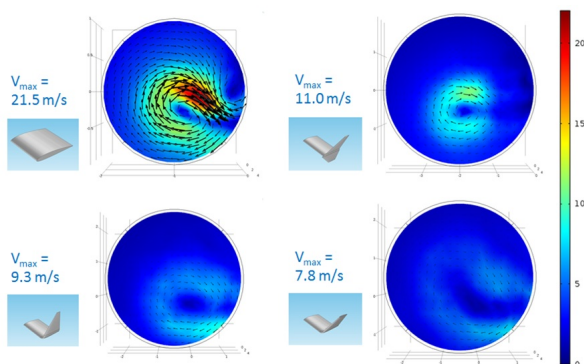
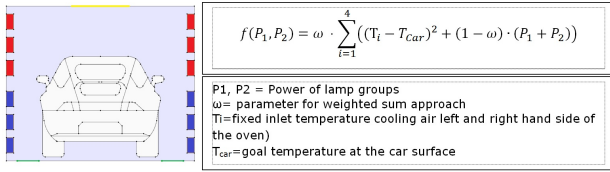


Figure 1



**Figure 2**