# Multi-Scale Modelling of Configurational Forces at Small Strains

**Markus Klassen*, Charlotte Kuhn‡, Sarah Staub†, Heiko Andrä†, Ralf Müller***

* Institute of Applied Mechanics, TU Kaiserslautern
Gottlieb Daimler Str., 67663, Kaiserslautern, Germany
mklassen@rhrk.uni-kl.de, ram@rhrk.uni-kl.de

‡ Computational Mechanics, TU Kaiserslautern
Gottlieb Daimler Str., 67663, Kaiserslautern, Germany
chakuhn@rhrk.uni-kl.de

† Fraunhofer Institute for Industrial Mathematics ITWM
Fraunhofer-Platz 1, 67663, Kaiserslautern, Germany
sarah.staub@itwm.fraunhofer.de, heiko.andrae@itwm.fraunhofer.de

## ABSTRACT

Microstructural optimization of materials has become more important during the last years in many engineering fields. Especially, in aerospace engineering, strong materials with a minimal weight are of high importance. But also when it comes to energy efficiency, industries like the automotive one benefit from such kind of materials. Furthermore, it can be observed in nature, that the microstructure of the material is of importance. For example bones and tissues as well as plants possess a microstructure consisting of fibres.

In the area of numerical simulation the consideration of the microstructure represents an important challenge. A full scale macroscopic approach would lead to exaggerated computation times. For this reason, numerical homogenisation is considered to reduce the computational effort. One alternative for this challenge is the $FE^2$ method with representative volume elements (RVE's), which is considered in the present work.

The presentation begins with the introduction of the basic concepts and equations of the framework. Furthermore, the concept of configurational forces is introduced. Afterwards the implementation of the $FE^2$ method in the finite element analysis program FEAP is discussed. When it comes to the homogenisation of configurational forces at small strains, special attention has to be given to the boundary conditions on the RVE. The difference of applying the displacement gradient or only its symmetric part as a boundary condition is explained in the work and shown by numerical examples. In addition, several benchmarks are presented where the importance of configurational forces in the homogenisation framework becomes apparent. Concluding remarks and an outlook end the presentation.

## REFERENCES

[1] V. Kouznetsova, W. A. M. Brekelmans and F. P. T. Baaijens, "An approach to micro-macro modelling of heterogeneous materials", *Comput. Mech.*, **27**, 37-48 (2001).

[2] S. Ricker, *Multi-Scale Modeling and Simulation in Configurational Mechanics*, PhD Thesis, TU Kaiserslautern, Germany, 2011.