6th European Conference on Computational Mechanics (ECCM 6)
7th European Conference on Computational Fluid Dynamics (ECFD 7)
11-15 June 2018, Glasgow, UK

A Multiscale Method for Discrete Fiber Network Models

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Keywords: *Multi-scale Method, Fiber Network, Paper Mechanics, Paper Forming*

The mechanics of paper depends on the properties of its fibers and bonds. Modeling paper as a network [1] will include effects of single fibers and bonds, capturing heterogeneous properties. In the ISOP (Innovative Simulation of Paper) project at Fraunhofer-Chalmers Centre, the forming process is simulated [2, 3]. To investigate the mechanical properties of the resulting simulated paper sheets a network approach is utilized.

Numerical investigation of fiber networks is demanding due to the large number of fibers and bonds, fluctuation of their properties, and the non-regular network structure. Multi-scale methods are useful tools to circumvent such problems. In this work a multi-scale approach for fiber networks is developed, based on a FEM-method for continua [4].

Consider a fiber network governed by a model resulting in an equation $Kx = F$, where K describes the network properties, x are node displacements, and F are applied forces. The idea of the multi-scale method is to consider a subset of all nodes, denoted coarse nodes, which in turn represents a coarse grid. At each coarse node a basis function is defined similarly as in the finite element method. By solving a system including the coarse nodes an approximation would be attained, however this approximation would leave out the fine scale effects of the heterogeneous network. Instead the coarse basis functions are modified by solving a local system at each coarse node, including surrounding fine nodes. These modified basis functions are thereafter used when solving the global system, resulting in an approximation of the network displacements now including effects from the fine scale.

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