Multiscale topology optimization of solid and fluid structures

This thesis considers the application of the topology optimization method to multiscale problems, specifically the fluid-structure interaction problem. By multiple-scale methods the governing equations, the Navier-Cauchy and the incompressible Navier-Stokes equations are expanded and separated leaving a set of micro- and macroscale equations for the interaction modeling. The topology optimization method is applied to the material design in order to optimize the pressure coupling properties of porous materials. Furthermore, by combining both the material design and the macroscopic modeling, it is shown that the material microstructure can be optimized with respect to application scale properties. A poroelastic actuator consisting of two saturated porous materials is optimized using this approach. Based on the homogenization of a fixed microstructure topology, material design interpolation functions are obtained for use in material distribution problems of a saturated poroelastic structure. Topology optimization is applied for the optimization of an impact absorbing structure and the fluid-structure-interaction of a pressurized lid. A third application considers the pure fluid flow in a microfluidic mixer. The mixing of a transported matter is optimized by means of topology optimization and it is shown that the optimized designs contain geometric elements such as slanted grooves and staggered herringbones also used in the literature. To ensure the manufacturability of the topology optimized designs a new explicit parametrization is proposed. It allows for casting/milling type manufacturing and ensures a binary design. The method is successfully applied to micromixer design.

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