# Design of 3d Woven Materials with Optimized Multifunctional Behavior

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## Abstract

Modern weaving and processing technologies enable the creation of very complex 3d woven materials at relatively low cost. Design of these materials, however, is typically driven by empirical guidelines and intuition of the materials design engineer. We present here a more formal, optimization-driven design framework for tailoring the microstructural topology of porous woven materials in a manner that maximizes the effective (bulk) material properties. Several properties are considered, including mass, mechanical stiffness, fluid permeability, and conduction properties, as well as various combinations of these properties to design high performance multifunctional materials. Numerical homogenization is used to estimate the effective (bulk) material properties from the woven unit cell topology. The corresponding design problem is posed using an inverse homogenization formulation that is then solved using projection-based topology optimization with gradient-based optimizers. As in typical projection-based approaches, the design and analysis meshes are distinctly separate and are coupled through the projection functions. This is critical for the considered problem as different models and meshes are used to capture the material system behavior under the different physics. Design and processing challenges will be discussed, including the very real need to incorporate fabrication uncertainty into the design formulation in future work. Optimized woven material topologies that were actually fabricated and experimentally tested will also be presented.