Optimal design of a fiber reinforced membrane

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Abstract

The usage of thin composite materials in industry, especially high performance industry is increasing. Thin composite materials have several benefits over traditional thin materials. Because of this, accurate simulations and optimal design of thin composite materials is crucial.

In this paper, we propose a FEM for an anisotropic membrane model and an algorithm for obtaining an optimal design thereof.

Construction of an anisotropic membrane in 3D is done by combining a transversely isotropic membrane constitutive tensor with two reinforcing, one dimensional, fiber material tensors. The FE model of the membrane is created using a tangential calculus approach and the membrane problem is discretized using the cut Finite Element Method (cutFEM), i.e., the membrane is modeled as an embedded surface within a fixed 3D solid mesh.

Optimization of the fiber material is carried out using an optimality criterion where the two fiber material distributions and the fiber orientations are optimized under a volume constraint.

Using this approach, the optimal design for the anisotropic membrane is obtained and the results are compared with an isotropic membrane model. Fiber orientations and distributions are illustrated from the initial design to the optimal design.

This approach allows for, e.g., shape optimization problems as well as extensions to dynamic problems where the membrane surface can be evolved through time without the use of re-meshing techniques. Another possible extension is to create more complex sandwich materials using one or more membranes of this type embedded into a bulk material.

Keywords: cutFEM, Membrane, Tangential Calculus, Fiber Orientation, structural optimization