Optimal Design of Laminated Composite Beams

This thesis presents an optimal design framework for the structural design of laminated composite beams. The possibility of improving the static and dynamic performance of laminated composite beam through the use of optimal design techniques motivates the investigation presented here. A structural model for the analysis of laminated composite beams is proposed. The structural analysis is performed in a beam finite element context. The development of a finite element based tool for the analysis of the cross section stiffness properties is described. The resulting beam finite element formulation is able to account for the effects of material anisotropy and inhomogeneity in the global response of the beam. Beam finite element models allow for a significant reduction in problem size and are therefore an efficient alternative in computationally intensive applications like optimization frameworks. Furthermore, the devised beam model is able account for the different levels of anisotropic elastic couplings which depend on the laminate lay-up. An optimization model based on multi-material topology optimization techniques is described. The design variables represent the volume fractions of the different candidate materials. Existing material interpolation, penalization, and filtering techniques have been extended to accommodate any number of anisotropic materials. The resulting optimization model is suitable for the simultaneous optimization of cross section topology and laminate properties in the optimal design of laminated composite beams. The devised framework is applied in the optimal design of laminated composite beams with different cross section geometries and subjected to different load cases. Design criteria such as beam stiffness, weight, magnitude of the natural frequencies of vibration, and the position of the cross section shear and mass center, are considered. The proposed optimal design framework can be applied to tailor the static and dynamic properties of laminated composite structures like wind turbine blades.

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