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Comparison of FMO, DMO, and CFAO for laminated composite structures

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Abstract
Fiber reinforced polymer materials are used in many applications where high stiffness and/or strength to weight ratios are required. Designing using composite materials is however a difficult task, and in order to design high performing composite structures it is advantageous to apply optimum design procedures for determining the optimum fiber orientation and orthotropy at every point in the structure. This work takes its form in free material optimization (FMO) developed in a finite element framework using layered shell elements. The focus point is the development of free material optimization in commercial codes using simple optimality criteria based procedures to determine the optimized design. The main objective is formulation and application of FMO to provide an initial estimate on the design of fiber reinforced composite structures. The parameterizations for FMO are the rotation and orthotropy of the stiffness tensor. The FMO formulation will include a patch formulation where parts of the structure are constrained to have the same material properties. Furthermore, a layered FMO formulation is developed.

Through the study a number of numerical examples are considered in order to benchmark FMO against discrete material optimization (DMO), and continuous fiber angle optimization (CFAO). DMO and CFAO are implemented in the in-house optimization code MUST (the MUltidisciplinary Synthesis Tool). DMO is a method to determine the optimum material from a discrete set of available materials based on the principles from multiphase topology optimization. For DMO the parameterization is the density for a set of predefined composite materials with corresponding rotations. In CFAO the material is chosen beforehand and is rotated to the optimum angle, thus the parameterization is the rotation angle of the material. The benchmark examples include stiffness optimization of single and multiple layered laminated composite structures. Furthermore, the design based on FMO is compared to the optimum designs from DMO and CFAO.

The optimizations are benchmarked using a set of numerical test examples, where minimum compliance is evaluated for the different approaches. The structural performances of the FMO, DMO, and CFAO are compared using the numerical test examples.
Keywords: Free Material Optimization, Laminate Optimization, Commercial Codes.