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Multi-Criteria Multi-Material Topology Optimization of Laminated Composite Structures including Local Constraints

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1. Abstract

In recent years there has been much research on structural optimization of laminated composite structures using multi-material topology optimization approaches. Most work has been related to design problems involving global criterion functions like compliance, eigenfrequencies, buckling load factors, and mass. However, recent work by the authors have also included local criterion functions in terms of failure criteria. This paper will present recent developments of multi-criteria multi-material topology optimization where both global criteria and local criteria are taken into account when solving the structural optimization problem. A number of practical design guide lines, referred to as manufacturing constraints, may also be included in the formulation.

The developments are illustrated for both monolithic fiber reinforced laminates and for design of sandwich type structures, where fiber reinforced polymer materials are combined with soft materials like balsa wood or foam material. The parametrizations used are all within the family of the Discrete Material Optimization (DMO) approach, i.e., it results in a gradient based optimization approach where weight factors determine the distribution of the candidate materials over the layered design domain. Increasing penalization is introduced in order to push the continuous design variables to 0-1 values. The multi-material design problems typically result in very many design variables and very many local strength criteria, where the number of strength criteria to include in the mathematical programming problem in the present approach is reduced by the use of aggregation functions such as p-norm measures or modified Kreisselmeier-Steinhauser (KS) functions. The design parametrization is associated with groups of elements (patches) having the same design variables, and the aggregated strength measures are typically associated with these patches in the current approach.

The presentation will discuss issues regarding penalization and aggregation strategies for the local strength criteria, which can be any type of typical failure criteria used for composites and core materials (max strain, max stress, Tsai-Wu, Puck, etc.). The examples will take outset in parametrizations used for fixed thickness laminate design problems but ongoing work on parametrizations for discrete thickness optimization combined with the solution of the multi-material distribution problem will also be presented. The examples include smaller academic benchmark examples and larger real-life design optimization problems with offset in wind turbine blade design problems.

2. Keywords

Laminate optimization, local criteria, multi-material topology optimization.