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COMPARISON OF DISCRETE MATERIAL OPTIMIZATION APPROACHES FOR OPTIMIZATION OF LAMINATED COMPOSITES

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Laminated composite structures are used in a number of high performance lightweight structures due to their high specific stiffnesses and strength. The laminated composites considered in this work contain layers of fiber reinforced polymer (FRP) materials, and the structures can both be monolithic and sandwich structures. In monolithic structures all layers consist of the same FRP material whereas sandwich structures typically have stiff outer layers consisting of FRP and inner layers consisting of soft core material like PVC foam, balsa wood, etc. Very often the designers are limited to orient the FRP material at predefined fiber angles, and thus the design problem is often discrete by nature.

Stegmann and Lund [1, 2] developed the Discrete Material Optimization (DMO) approach for solving structural optimization problems involving laminated composites. FRP material with different predefined fiber angles are considered as candidate materials together with possible core materials in case of designing sandwich structures. The discrete optimization problem is converted to a continuous problem using interpolation functions with penalization. This approach makes it possible to apply efficient gradient based optimization algorithms for solving the multi-material optimization problem.

The DMO approach has been demonstrated for a number of applications, see e.g. [1–4].

The original DMO interpolation functions introduced in [1, 2] did have some problems in enforcing a unique 0-1 design, and thus several other interpolation approaches and algorithms have been introduced in recent years. [5] proposed series of linear equality constraints to prevent the total sum of the candidate design variables from exceeding unity and used a quadratic penalty constraint to gradually force the design variables to their discrete bounds. [6] formulated multi-material variations of the SIMP and RAMP interpolation schemes known from topology optimization. [7] introduced the Shape Functions with Penalization (SFP) scheme based on the shape functions of a quadrangular first order finite element, using only two natural coordinates to interpolate between four candidate materials. [8] generalized the SFP approach to any number of candidate materials by their Bi-valued Coding Parameterization (BCP) scheme. As with the SFP approach, the advantage of BCP in contrast to the other interpolation approaches is that the number of design variables is lower than the number of candidate materials. Finally, [9] proposed a series of non-linear equality constraints, which were added as a penalty term to the objective function, thereby penalizing intermediate valued design variables.

In this work the above mentioned DMO approaches have been compared for optimization problems involving compliance, eigenfrequency, buckling and multi-criteria design problems, and conclusions in regard to computational efficiency together with performance and discreteness of the final design are presented.

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