IV ECCOMAS Thematic Conference on the Mechanical Response of Composites
Composites 2013
A. Suleman, P. Camanho, et al. (Editors)

Comparison of parameterization schemes for solving the discrete material optimization problem of composite structures

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ABSTRACT

In the context of weight reduction challenges in aerospace, automotive, and energy engineering problems, composite materials are gaining a revived interested. Because of the problem complexity and the large number of design variables, their design of composite structures is greatly facilitated by using optimization techniques.

While several formulations have been proposed for composite structure design, Stegmann and Lund [1] have showed that composite optimization can take advantage of the topology optimization approach. The fundamental idea of the Discrete Material Optimization (DMO) approach is 1/ to formulate the composite optimization problem as an optimal material selection problem in which the different laminates and ply orientations are considered as different materials and 2/ to solve the optimization problem using continuous existence variables. To transform the discrete problem into a continuous one, one introduces a suitable parametrization identifying each material by a unique set of design variables while the material properties are expressed as a weighted sum of all candidate materials. Using DMO approach, one can solve within a common approach, different design problems such as laminate distribution problem, stacking sequence optimization...

The inherent difficulties of the discrete material selection using topology optimization are 1/ to find efficiency interpolation and penalization schemes of the material properties and 2/ to be able to tailor an efficient solution algorithm to handle very large scale optimization problems.

Besides the reference DMO scheme by Lund and his co-authors, other interpolation schemes have been proposed: In this paper, work we are considering and comparing DMO with two other schemes namely the Shape Function with Penalization Parameterization (SFP) by Bruyneel [2] and it recent extension, the Bi-value Coding Parametrization (BCP) by Gao et al. [3]. In particular, the work considers the different schemes in the perspective of solving large-scale industrial applications. The work considers several aspects of the different schemes:

- Nature of the different interpolation schemes,
- Penalization strategies (power law (SIMP), RAMP, Tsai-Halpin or polynomial),

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- Number of design variables, the size and complexity of the optimization problem,
- Sensitivity to local optima, to the initial design variable, and the development of continuous penalization techniques,
- Ability to be extended to various formulations from compliance problems to local restrictions and buckling.

As a major drawback, DMO, SFP and BCP approaches increase dramatically the number of design variables. Because of the computational burden to solve the optimization problems, in most of DMO implementations, the considered structural responses are generally limited to compliance-like objective functions. In order to extend the DMO formulation, the work investigates the selection of the most appropriate and efficient optimization algorithms to handle the problems. Different schemes of the sequential convex programming are compared. At first the classic schemes MMA and CONLIN are tested. Then more advanced schemes of the MMA family (Bruyneel et al. [4]) are experimented.

The work and the comparisons are carried out on several numerical applications related to the selection of optimal local fibre orientations (with up to 36 candidate material orientations) in membrane and shell aerospace or automotive structures. The various numerical test problems include academic examples and benchmarks inspired by industrial applications.

Acknowledgements

This work has been supported by the Walloon Region of Belgium and SKYWIN (Aerospace Cluster of Wallonia) through the project VIRTUALCOMP (Contract RW-6293) and the 111 Project (B07050) of The People’s Republic of China.

References

[1] Stegmann J., E. Lund (2005). Discrete material optimization of general composite shell structures. *IJNME*, 62: 2009-2027

[2] Bruyneel M (2011). SFP - a new parameterization based on shape functions for optimal material selection: application to conventional composite plies. *SMO*, 43(1): 17-27

[3] Gao T., W. Zhang, P. Duysinx (2012). A bi-value coding parameterization scheme for the discrete optimal orientation design of the composite laminate. *IJNME*, vol 91 (1), 98-114

[4] Bruyneel, M., Duysinx P. & Fleury C. (2002). A family of MMA approximations for structural optimization. *SMO*, 24 (4), 263-276.