On Challenges and Solutions of Topology Optimization for Aerospace Structural Design

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Abstract

While recent years have witnessed industrial application success of Topology Optimization (TO) as an efficient technique for concepts generation in structural design, the dominating method of TO, namely the SIMP method or the density method, confines to linear elastic condition. The linear elastic limitation leads to **the first challenge** related to the structural functional performance. In fact, the real life Aerospace structural design is very complex (multiple loads, both statics and dynamics, nonlinearities, multi-physics counting fatigue, thermal and structural-fluid interaction). TO needs further integration into the design process to meet functional requirements. Drawn from a real life scenario, the process flow of traditional structural design is compared to the process flow of TO driven structural design. The value of TO in the structural design process is explained. The computational scheme to iteratively solve the TO problem and the complete structural design problem is proposed to overcome the challenge.

Commercial TO tools (such as OPTISTRUCT and GENESIS) that are widely used in industry employ gradient based searching algorithm in order to obtain optimum at minimal computational time for industrial size problems. However, optimal solution is a local minimum and may be sensitive to the problem parameters. This leads to **the second challenge** to rationally verify the uniqueness of the topology optimized design. In turn, it requires to develop a practical sensitivity study strategy to solve the TO problem with respect to the problem parameter changes. A cube example is illustrated to outline a generic strategy in order to verify the uniqueness of the optimal topology.

The third challenge is related to the manufacturing feasibility and interpretation of the optimal topology. The topology optimized design, even being

enforced with applicable conventional manufacturing constraints, is often not directly manufacturable. To convert optimal topology to a manufacturing design, moderate to significant manual modification of the topology layout is necessary. This user interpretation process of the TO results is subjective in nature as the user may not fully trust results, be unable to capture the key concept from the results, be unable to find a good manufacturing method. As a result, TO needs further integration with the manufacturing process in order to be able to fabricate the highest performing topology at reasonable cost. The cube example is illustrated to establish practical rules and guidelines to interpret optimal topology.

The manufacturing challenge prompts further thoughts on the use of Additive Manufacturing (AM) in order to retain much, if not all, of the original organic yet complex optimal topology. This emerging area of combining TO and AM could be further explored for designing better Aerospace structures.