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STRENGTH-ORIENTED DESIGN OF MULTI-MATERIAL MICROSTRUCTURES USING TOPOLOGY OPTIMIZATION

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Structural optimization plays an important role in the construction industry, leading to more material-efficient structures, promoting then the sustainability of this sector. One of the strategies to perform structural optimization is through Topology Optimization (TO). Single-Material Topology Optimization (SMTO) has been extensively studied over the past decades (see e.g., [1]). Regarding the Multi-Material Topology Optimization (MMTO), there is not that much work especially in microstructural design. MMTO is a current research topic, boosted by rapid developments in Multi-Material Additive Manufacturing (MMAM) (see e.g., [2]).

This work addresses MMTO of a periodic composite material unit-cell considering two solid materials plus void, with properties predicted by homogenization, using strength and stiffness design criteria. Firstly, the compliance minimization with mass constraint MMTO problem is solved here. Then, one performs a stress-based MMTO problem where the maximal von Mises stress is minimized in the unit-cell. Two different types of design solutions are investigated in this latter case. On one hand, the two solids coexist being bonded together across sharp interfaces. On the other hand, a Functionally Graded Material (FGM) is obtained as an extensive smooth variation of material properties on account of varying composition's volume fractions of both solids throughout the design domain.

The results show that multi-material designs can outperform single-material ones, both in stiffness and strength design criteria [3]. More specifically, the obtained optimal designs of the compliance-based MMTO are stiffer and stronger than the single-material counterparts for the same mass requirement, on account of removing all void present in the microstructure. On the other hand, the stress-based MMTO designs for the same material volume show a decrease in the maximum stress on the microstructure on account of allowing an increased compliance. The FGM designs approximate fully stressed designs which excel in stress mitigation.

References

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