Parallel Multi-scale Concurrent Optimization of Lightweight Lattice Materials

Jun Yan*, Tao Yu*, Sixu Huo*, Kun Yan*, Xianghai Chai†

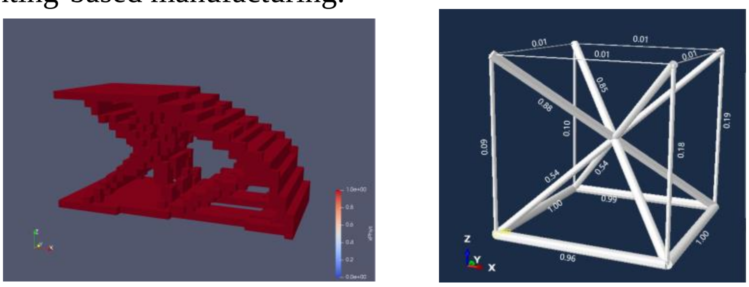
* State Key Laboratory of Structural Analysis for Industrial Equipment, Department of Engineering Mechanics, International Research Center for Computational Mechanics
Dalian University of Technology, Dalian 116024, China
e-mail: yanjun@dlut.edu.cn

† Department of Discipline Engineering
AECC Commercial Aircraft Engine Co., Ltd., Shanghai 200241, China
Email: chaixianghai@sohu.com

ABSTRACT

With the rapid development of additive manufacturing technologies, lightweight porous materials have been increasingly utilized in many application areas as load-bearing members, heat exchangers, energy absorbers, and key components of aircraft engines, etc. An important kind of such materials is the so-called “structured porous materials,” which are featured porous constructions with periodical microstructures. Structured porous materials show unique designability across both the microscale (i.e., design of microstructural patterns) and macroscale (i.e., design of structural configurations). However, multiplying the number of dimensions of the structural design space by that of the microstructural design space leads to a large number of dimensions for the concurrent design, making it almost unsolvable by conventional single-scale design approaches.

A computationally effective solution framework for multiscale structural topology optimization was established. A so-called “porous anisotropic material with penalty” (PAMP)-based method was developed to resolve the challenging issues arising from the ultra-large dimensions of the design space [1-2]. The asymptotic homogenization theory and EMsFEM were utilized to realize the coupling of the materials and structures. The concurrent multiscale topology optimization was established for minimum structural compliance problems, and was extended to thermoelastic and coupled thermal–elastic lattice structures (Figure 1). The optimization result reveals new design features and becomes more conducive to 3D printing-based manufacturing.



(a) Optimal structural macroscopic configuration (b) Optimal material microscopic configuration

FIGURE 1. Design of lightweight lattice materials based on multiscale topology optimization.

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