Homogenization-based topology optimization integrated with elastically isotropic lattices for additive manufacturing of ultralight and ultrastiff structures

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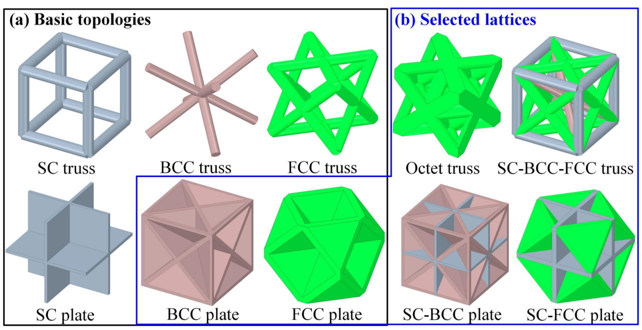
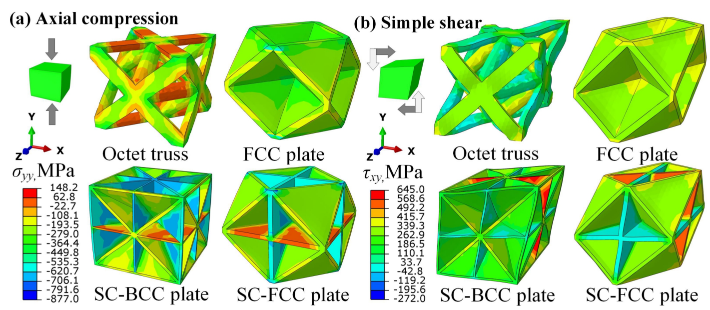
1. Introduction

The integration of topology optimization with lattice structures has shown great potential for the additive manufacturing (AM) of lightweight structures with superior mechanical properties and multifunctional characteristics. To further improve the design manufacturability, structural efficiency, structural isotropy and computational efficiency, the homogenization-based topology optimization (HMTO) method was proposed to integrate with plate–lattices exhibiting superior mechanical properties and excellent elastic isotropy. The validity of the proposed method was demonstrated by comparing the optimized models with conventional models composed of truss–lattices and solid materials. Results show that the proposed method highly improves stiffness and energy absorption capability.

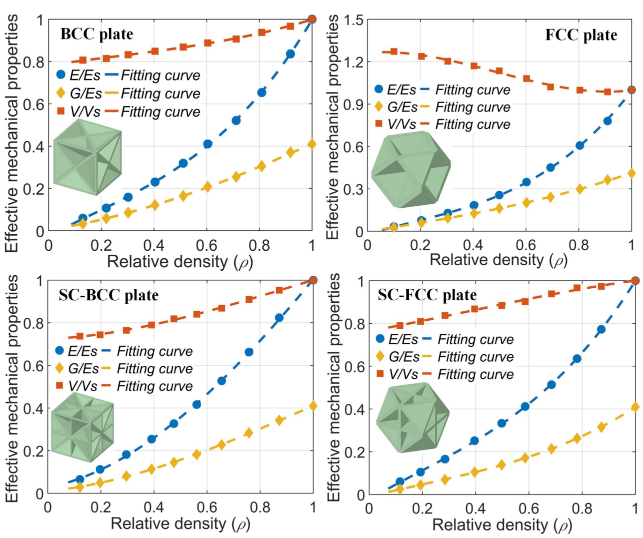
2. Evaluation of mechanical properties and elastic isotropy



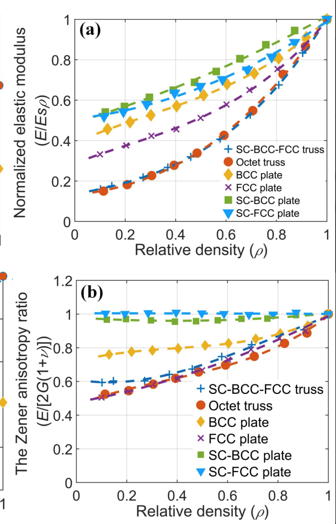
selection of lattice structures



Evaluation of basic mechanical properties of lattice structures



Effective mechanical properties of lattice unit cell



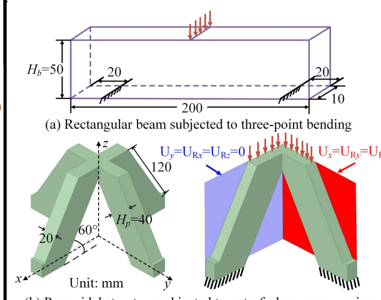
Elastic modulus and isotropy

3. Topology optimization

$$\min_{\rho_e} : c(\rho_e) = \mathbf{U}^T\mathbf{K}\mathbf{U} = \sum_{e=1}^{N} \mathbf{u}_e^T \mathbf{k}_e \mathbf{u}_e \quad \mathbf{K}\mathbf{U} = \mathbf{F}$$

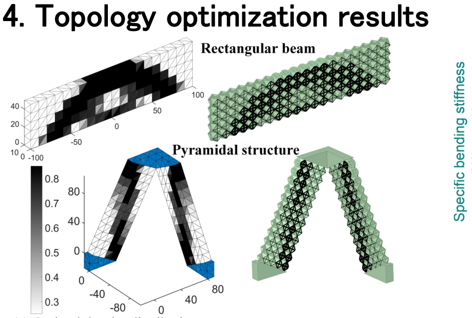
$$\frac{V(\rho_e)}{V_0} = f \qquad 0 \le \rho_{\min} \le \rho_e \le \rho_{\max} \le 1$$

Topology optimization problem

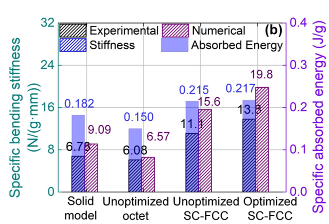


Topology optimization model

4. Topology optimization results



Optimal density distribution and constructed models



Highly improved stiffness and energy absorption capability of optimized models obtained by the proposed method

5. Conclusion

1. The plate–lattices exhibit much higher elastic moduli than the truss–lattices especially at low relative densities.
2. The SC–BCC and SC–FCC plate–lattices have good elastic isotropy, whereas the octet truss–lattice and FCC plate–lattice are relatively more anisotropic.
3. Comprehensively considering the superior structural efficiency and excellent elastic isotropy, the SC–BCC and SC–FCC plate–lattices are ideal options to be integrated with the HMTO method.
4. The proposed method can be expected to improve design manufacturability, structural efficiency, structural isotropy and computational efficiency.