Topology Optimized Hybrid Unit Cell Geometry

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BACKGROUND

"How would you determine if it's too little, too much, or just right?"

In topology optimization within material science and engineering, assessing whether material distribution is 'too little,' 'too much,' or 'just right' involves evaluating how material allocation impacts design performance and efficiency. The goal is to minimize material use while maintaining structural integrity.

RESEARCH OBJECTIVES

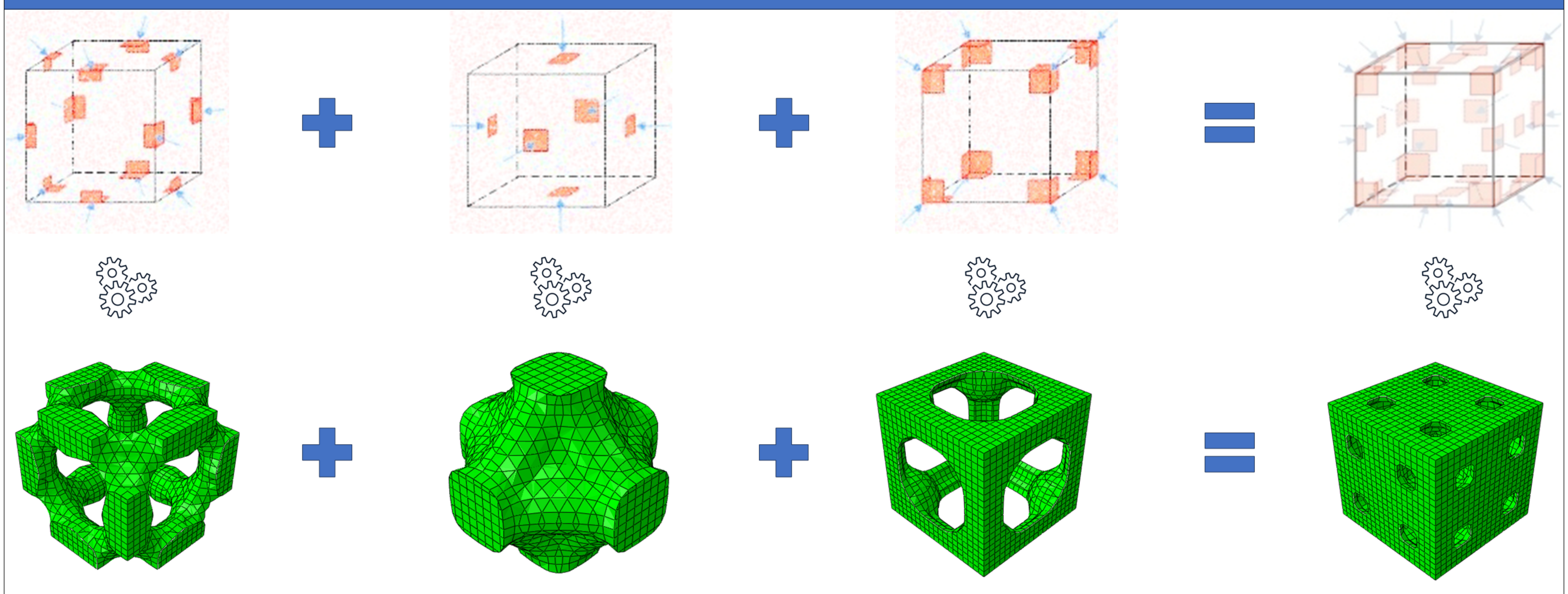
This process aims to advance the understanding of structural behavior under varied conditions and facilitate the development of novel, optimized unit cell geometries, thereby providing insights into lattice structure design for practical engineering applications.

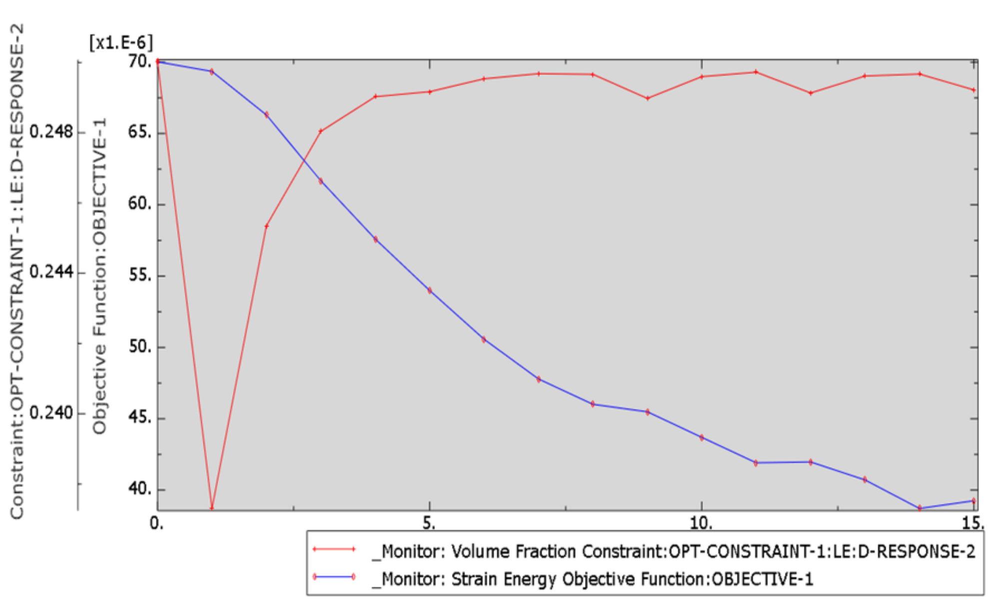
- Simulate operational conditions to establish a basis for optimization.
- Apply iterative optimization to identify potential unit cell geometries.
- Develop a hybrid unit cell geometry based on simulation insights.
- Evaluate the feasibility of the chosen geometry for its application in lattice structures.

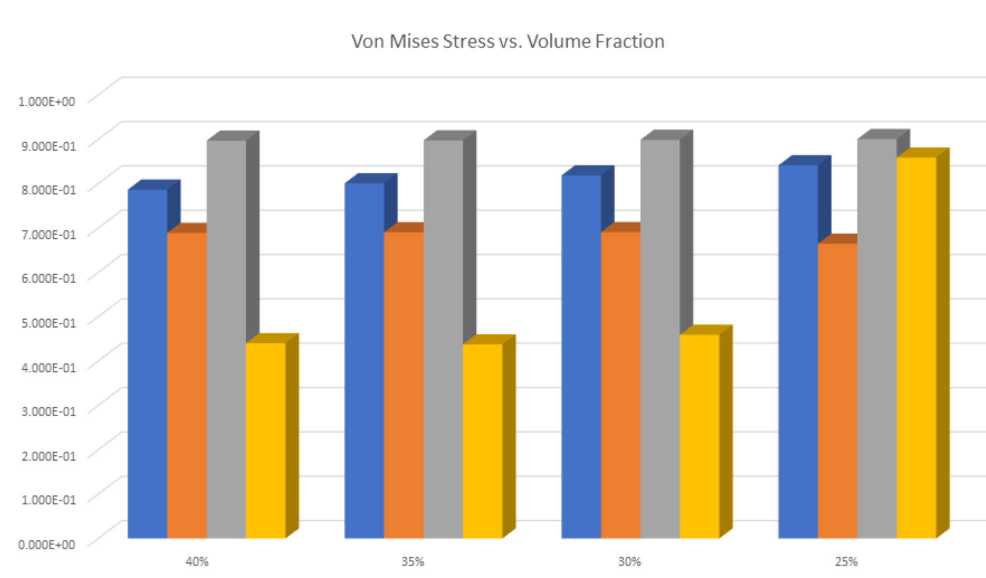
METHODOLOGY

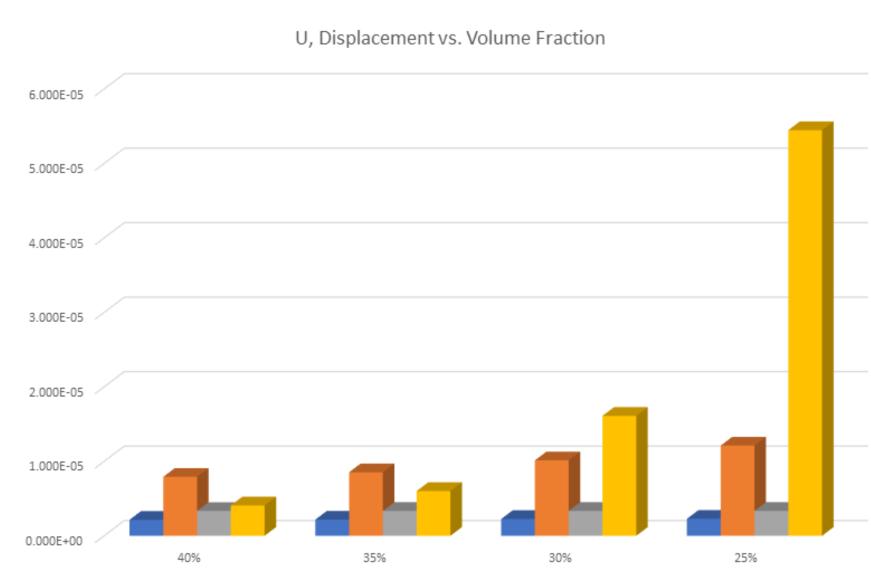
In this study, generalized material properties were applied to a 5 mm^3 cubic specimen subjected to three distinct loading conditions, which facilitated the topology optimization of three unit cell geometries: Edge-Centered Cubic (ECC), Face-Centered Cubic (FCC), and Vertex Cubic (VC) each with varying volume constraints. The SIMP (Solid Isotropic Material with Penalization) topology optimization technique was applied to refine these geometries. Subsequently, a hybrid unit cell geometry (HC) was designed using advanced optimization techniques, and its mechanical performance was meticulously characterized and compared to assess its effectiveness under the specified loading conditions.

RESULTS









DISCUSSION

As the optimization progresses, strain energy consistently decreases, showing effective minimization by the SIMP algorithm. Despite the volume fraction constraint, which balances energy reduction with constraint adherence, the hybrid unit cell geometry performs better mechanically under loading conditions. However, reducing the volume fraction from 40% to 25% results in decreased mechanical performance, evident in increased stress and deformation, indicating that less material or suboptimal geometry compromises structural efficiency.

CONCLUSIONS

In summary, optimization process is effectively minimizing strain energy function within the constraints of volume fraction. The hybrid unit cell geometry shows superior mechanical performance, but reducing the volume fraction constraint seems to negatively impact this performance. This trade-off between volume fraction and mechanical performance is crucial for optimizing design under practical constraints.

KEY REFERENCES

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