Paper ID: 69915
oral
student

IAF MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Interactive Presentations - IAF MATERIALS AND STRUCTURES SYMPOSIUM (IPB)

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SPACE STRUCTURE BUILDING BLOCK INSPIRED BY DEEP-SEA GLASS SPONGES

Abstract

Future space missions and space exploration ambitions significantly rely on large space structures. A recent automated construction paradigm made of modular lattice elements (building block) and relative robots became a viable approach to construct ultra-large multi-functional space structures. This construction approach proposes inherent serviceability and expandability, in addition to complexity independence of size. However, free-free floating space structures under construction, and operating in on-orbit disturbance load environments suffer from continuous surface deformation, vibration and remain wobbly. Having an unstable spatial platform will inevitably affect the construction speed, assembly reliability, and construction agent design complexity. For instance, as space telescope structures, surface elastic deformation is one of the top-level structural requirements.

Considering the discreet Lattice systems, the structural elastic deformation and dynamic behavior are dictated by the building block mechanical property. Aiming for lightweight, high specific stiffness structure with excellent compacting stowage, this paper provides a unique robust building block design inspired by deep-sea glass sponges which feature hierarchical architecture and outstanding buckling resistance. In a deep-sea sponge, spicules are constructed to form a double diagonal strut reinforcing a regular square grid, creating a chequerboard-like pattern of open and closed cells.

To study the sponge's skeletal architecture mechanical benefits for three-dimensional building blocks, we analyze the performance enhancement with Simple Cube and Cube-octahedron through the combination of finite element simulations and mechanical tests. By using ABAQUS/Standard software to simulate the uniaxial compression test, specific stiffness and yield strength of the building block are evaluated. Meanwhile, experimental specimens with/without sponge reinforcement are fabricated via micro-3D printing with up to 25 m resolution to achieve the required accuracy. We further explore the building block response under different load angles for the two building blocks. Finally, seeking better structural stability, our findings show the viability of achieving structural dimensional stability passively through proper building block design.