11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

Nonlinear Elastic and Plastic Response of Chiral, Anti-chiral and Hierarchical Periodic Solids

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Key Words: *Buckling, Plasticity, Chirality, Hierarchy, Cellular Solids.*

Chiral, anti-chiral and hierarchical periodic patterns are crucial to understanding and emulating many living and non-living structural systems at different scales, including molecules, enzymes, and the microstructure of nacre. Studying the mechanical behavior of these structures, however, is relatively new and could significantly impact the design of meta-materials and multifunctional structural systems. In this study, analytical approaches for obtaining the bifurcation response of 2D (honeycombs) and 3D (foam) tessellated structures are introduced. The methods on the nonlinear response lead to closed-form relations for the post-buckling response of the tessellated pattern under a general state of stress, and is applied to a representative volume element (RVE) of the structure. In addition, a comprehensive analytical, numerical and experimental study on the elasto-plastic response of a series of novel periodic structures including hierarchical, chiral and anti-chiral honeycomb structures with triangular, square and hexagonal unit cells are performed. The elastic properties of the cellular lattices are also obtained through the energy method, and the plastic collapse strength of the structures is determined through the upper-bound collapse limit, allowing closed-form expressions for the elastic-plastic behavior of the structures. The findings from the analytical expressions are confirmed by the finite element analysis.