Study on the mechanical properties and energy absorption characteristics of bionic variable amplitude TPMS structures

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Abstract:

Introduction: The three-period minimal surface (TPMS) structure has great potential in the fields of lightweight and energy absorption due to its high strength, high porosity and self-supporting characteristics. However, previous studies have predominantly focused on aspects such as wall thickness, unit cell size, periodicity, and level set values. The impact of amplitude factors on the topological shape and mechanical properties of TPMS structure has not been fully elucidated.

Methods: Inspired by the amplitude characteristics of cuttlefish bone structure, this paper proposes a design method of TPMS structure with variable amplitude. Firstly, taking the classical Primitive, Gyroid and Diamond structures as the research objects, the influence of amplitude on the topological morphology and relative density of TPMS structure was analyzed by parametric method. Subsequently, the quasi-static compressive mechanical properties and energy absorption capacity of Gyroid structure were studied by experiments and numerical simulations.

Results: The change of the amplitude leaded to a significant change in the topological morphology of the structure, but the maximum relative density of the structure only changed by 1.5 %. The deformation modes of Gyroid structures of different amplitudes were identical, but as amplitude increased, mechanical properties and energy absorption capacity such as elastic modulus, yield strength and specific energy absorption increased.

Conclusions： The results indicated that the amplitude change has little effect on the relative density and deformation mode of the TPMS structure, but it can significantly regulate the mechanical properties of the structure on a large scale. With an increase in the amplitude factor, the densification strain of the structure slightly decreased, while the energy absorption capacity increased significantly. The research content can guide the design for the development of tissue scaffolds or energy-absorbing devices.

Keywords: Lattice structure; Triply periodic minimal surfaces; Variable amplitude; Mechanical properties; Energy absorption