Hedayati, R.; **Sadighi, M.**; **Mohammadi-Aghdam, M.**; **Zadpoor, A. A.**
Analytical relationships for the mechanical properties of additively manufactured porous biomaterials based on octahedral unit cells. (English) Zbl 1443.74053
Appl. Math. Modelling 46, 408-422 (2017).

Summary: Additively manufacturing (AM) techniques make it possible to fabricate open-cell interconnected structures with precisely controllable micro-architectures. It has been shown that the morphology, pore size, and relative density of a porous structure determine its macro-scale homogenized mechanical properties and, thus, its biological performance as a biomaterial. In this study, we used analytical, numerical, and experimental techniques to study the elastic modulus, Poisson's ratio, and yield stress of AM porous biomaterials made by repeating the same octahedral unit cell in all spatial directions. Analytical relationships were obtained based on both Euler-Bernoulli and Timoshenko beam theories by studying a single unit cell experiencing the loads and boundary conditions sensed in an infinite lattice structure. Both single unit cells and corresponding lattice structures were manufactured using AM and mechanically tested under compression to determine the experimental values of mechanical properties. Finite element models of both single unit cell and lattice structure were also built to estimate their mechanical properties numerically. Differences in the bulk mechanical properties of struts built in different directions were observed experimentally and were taken into account in derivation of the analytical solutions. Although the analytical and numerical results were generally in good agreement, the mechanical properties obtained by the Timoshenko beam theory were closer to numerical results. The maximum difference between analytical and numerical results for elastic modulus and Poisson's ratio was below 6%, while for yield stress it was about 13%, both occurring at the relative density of 50%. The maximum difference between the analytical and experimental values of the elastic modulus was $< 15\%$ (relative density$= 50\%$).

MSC:

74-10 Mathematical modeling or simulation for problems pertaining to mechanics of deformable solids

74E30 Composite and mixture properties

Keywords:

additive manufacturing; porous biomaterials; elastic properties; octahedral; finite element; analytical solution

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