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Mechanical Characterization of Porous 3D-printed Polymer-Derived Ceramics

Youjian Li[1], Hamidreza Yazdani Sarvestani[2*], Hossein Mofatteh[1], Vahid Karamzadeh[2], Behnam Ashrafi[2], Javad Gholipour[2], Abdolhamid Akbarzadeh[1,3*]

[1]*Department of Bioresource Engineering, McGill University, Montreal, Canada*
[2]*Aerospace Manufacturing Technology Center, National Research Council Canada, Montreal, Canada*
[3]*Department of Mechanical Engineering, McGill University, Montreal, Canada*
[*] Corresponding authors; E-mail address: hamid.akbarzadeh@mcgill.ca (A.H. Akbarzadeh); Hamidreza.YazdaniSarvestani@cnrc-nrc.gc.ca (H. Yazdani Sarvestani)

ABSTRACT

The mechanical characterization of bulk polymer-derived ceramics (PDCs) presents a notable challenge due to the inherent porosity introduced during pyrolysis, which complicates accurate determination of material properties. Conventional methods often overlook the voids formed by resin evaporation, resulting in inaccurate estimations of bulk stiffness. To address this limitation, we propose a methodology to estimate Young's modulus of bulk 3D-printed PDCs, providing a more precise understanding of their mechanical behavior. Hollow cylindrical specimens with varying wall thicknesses were fabricated using a liquid crystal display 3D printer. Micro-computed tomography scanning was employed to investigate the porous structure of these specimens, enabling the calculation of their densities and porosities. Using the reconstructed images, cubic mesh elements were generated for each sample, and finite element analysis (FEA) was conducted to simulate their elastic deformation under compression. A hypothetical bulk stiffness (E_{bs}) was assigned to the models, and the stiffness of the cylindrical specimens (E_{cs}) was derived. In parallel, compression tests were performed on the 3D-printed cylindrical samples to experimentally determine their stiffness (E_{ce}). Since the geometric models used in both the simulations and experiments were identical, the ratio of the true bulk Young's modulus (E_b) to E_{ce} was found to equal the ratio of E_{bs} to E_{cs}, enabling the calculation of E_b. This approach offers a robust framework for determining the bulk material properties of porous materials, including engineering ceramics and biological materials.