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NUMERICAL MODELING OF THE MECHANICAL BEHAVIOR OF ANISOTROPIC PATTERNED HYDROGEL

Tao Jin*, **Ilinca Stanciulescu**

Department of Civil and Environmental Engineering, Rice University, Houston, TX 77005, USA

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Poly(ethylene glycol) diacrylate (PEGDA) hydrogel is a soft bio-inspired material that can be potentially used to fabricate artificial heart valves in tissue engineering. An appropriate constitutive model for patterned PEGDA hydrogel can help us understand its mechanical behavior and optimize its patterning process. This work focuses on the constitutive modeling of patterned PEGDA hydrogel and utilizes finite element analysis to simulate its mechanical behavior under uniaxial tension, compression and three-point bending tests.

Anisotropy and nonlinearity are two prominent characteristics of patterned PEGDA hydrogel. A homogenized fiber reinforced material model can capture these phenomena and is used in this work to simulate patterned PEGDA hydrogels with different fiber-ratios and fiber-orientations. Embedded fibers are smeared into the matrix material and patterned PEGDA hydrogel is treated as homogenous. Different fiber-orientations can be reflected by the structural tensors introduced in the material model. Different fiber volume ratios can be represented by adequate choices of the material parameters. Material stability can be ensured when the material model satisfies certain generalized convexity condition, among which are the strong ellipticity condition and the polyconvexity condition. Calibrating the material parameters in the material model is difficult particularly due to the challenges one encounters when trying to correlate them with material or geometrical properties of the system. By means of taking into consideration how fibers are distributed in patterned PEGDA hydrogels, we successfully calibrate the material parameters. The numerical results from finite element simulations are then compared with the experimental data recorded in various mechanical tests and good matches between them are observed. Further testing confirms the potential of this material model to predict the mechanical behavior of hydrogels with different fiber-ratios and patterns. Thus, the homogenized fiber reinforced material model can accurately and comprehensively capture characteristics of patterned PEGDA hydrogel and can be used in numerical simulations of artificial heart valves fabricated utilizing this material.

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