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Constitutive modeling and characterization of nanocomposite hydrogel for blast resistant materials

Imam, Muhammed; Sain, Trisha, North Carolina A & T State University, United States

ABSTRACT

In the recent trend of advanced material research, manufacturing novel materials with improved properties and multifunctionality is an important focus across disciplines. As a material, hydrogel finds several applications in the area of biomedical engineering. They are used widely in tissue regeneration, scaffolding, drug delivery, etc. However, using hydrogels for mechanical load bearing application is still limited because of its poor stiffness and low toughness. Like other polymers hydrogels have viscoelasticity which indicates it has potentials to be used as an energy absorbing material. Researchers have already been working on producing tough hydrogels by manufacturing double network hydrogels and nanocomposite hydrogels. As expected, the area of research on hydrogels greatly focus on its material science and chemistry perspective and to a lesser extent on constitutive characterization of the material. In order to produce a superior material out of hydrogels, which will have improved mechanical properties and multifunctionality, a mathematical framework needs to be developed for characterizing the constitutive response of these materials. A physically motivated mathematical model would essentially fasten manufacturing novel hydrogels for various engineering applications. In this study, the goal is to develop a constitutive model for predicting the high rate response of nanocomposite hydrogels. The model is proposed in finite deformation framework because deformation associated with hydrogel is substantially higher than other polymers. In order to predict the viscoelastic response of hydrogels a time-dependent nonlinear stress–strain law is proposed where parameters evolve over time. The constitutive model consists of several branches of spring and dashpot combinations to account for the viscoelastic property in terms of multiple characteristic relaxation times. The nonlinear behavior is modeled using Arruda–Boyce hyperelastic potential function to capture the high stretch behavior in hydrogel. Experimental stress relaxation data from literature for covalently crosslinked alginate hydrogel was fitted to find the characteristic relaxation times. The requirement for a blast resistant material is to have moderately high stiffness, high energy absorbing capacity, with significantly high fracture toughness and preferably a self-healing capacity. The model will also be extended to consider the stimuli sensitive behavior of the hydrogels and eventually will focus on providing guidelines for manufacturing hydrogels which can be used as blast resistant materials.