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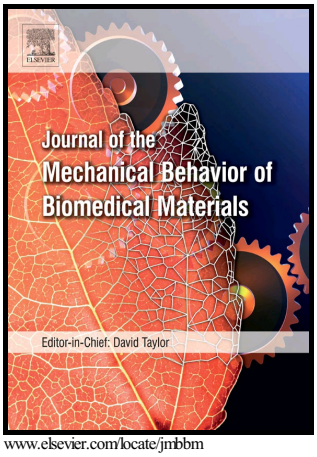
A.D. Drozdov, J. deClaville Christiansen



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Double-network gels with dynamic bonds under multi-cycle deformation

A.D. Drozdov* and J. deClaville Christiansen
Department of Materials and Production
Aalborg University
Fibigerstraede 16, Aalborg 9220, Denmark

Abstract

Application of double-network (DN) gels with dynamic bonds as implants for repair of damaged and degenerate cartilage tissue and their use as synthetic non-degradable scaffolds for growth, proliferation and differentiation of stem cells requires understanding of the mechanical behavior of these materials under cyclic deformation. A constitutive model is developed for the viscoelastic and viscoplastic responses of DN gels with covalent and non-covalent junctions under multi-cycle loading. Viscoelasticity is treated as breakage and reformation of temporary junctions driven by thermal fluctuations. Viscoplasticity is thought of as sliding of permanent junctions with respect to their initial positions in the polymer network. Adjustable parameters in the governing equations are found by fitting observations in tensile loading–unloading tests with various maximum strains and multi-cycle tests with monotonically increasing maximum elongation ratios per cycle on two DN gels with physical junctions formed due to hydrogen bonds and ionic complexation. Numerical analysis demonstrates the ability of the model not only to describe observations correctly, but also to predict the mechanical response in multi-cycle tests with sophisticated deformation programs. Quantitative and qualitative effects of metal-coordination bonds on the mechanical behavior of supramolecular gels are revealed by simulation.

Key-words: Double-network gel; Dynamic bonds; Cyclic deformation; Mullins effect; Fatigue

1 Introduction

Hydrogels are "soft and wet" materials formed by water-swollen three-dimensional networks of hydrophilic chains bridged by covalent and non-covalent bonds (Osada and Gong, 1998). Mechanical

*E–mail: aleksey@mp.aau.dk