

Modelling pore closure in slowly degrading poroelastic materials driven by fluid flow

Matthew Ghosh¹, Matthew Hennessy², Andreas Muench³, Sarah Waters⁴

¹ University of Oxford, United Kingdom. sann6739@ox.ac.uk

² University of Bristol, United Kingdom. matthew.hennessy@bristol.ac.uk

³ University of Oxford, United Kingdom. andreas.muench@maths.ox.ac.uk

⁴ University of Oxford, United Kingdom. sarah.waters@maths.ox.ac.uk

Paper ID: 296

[Symposium S7: Mechanics of soft materials and structures](#)

[Extended Abstract](#)

Abstract

Certain poroelastic materials, such as hydrogels, weaken or degrade upon interaction with salts, enzymes, or simply the interstitial fluid itself; this process is exploited in various biomedical applications, such as tissue engineering and drug delivery. Each soft material in these applications is selected on account of its mechanism and timescale of degradation, which is usually much longer than that of poroelastic relaxation. In this work, we build a model of a weakening poroelastic material subject to an external solute-carrying flow. The solute is assumed to react with the material and reduce the Young's modulus. Our model exhibits a three-way coupling between poroelastic deformation, solute transport and solute-induced weakening. We analyse a one-dimensional system subject to a fixed pressure drop and investigate how weakening affects the long-term evolution of the material. Guided by finite element simulations, we find that, in scenarios where the weakening timescale is much longer than the timescale of poroelastic relaxation, the material evolves in two distinct phases: an initial phase dominated by poroelastic deformation, followed by a quasi-steady phase in which solute-induced weakening causes the material to compress further and the porosity to decrease. We use asymptotic analysis to further investigate this quasi-steady phase and generate analytical expressions for the porosity, Young's modulus and solute concentration. Consequently, we

determine conditions on the pressure drop and material parameters for which material weakening leads to pore closure. We identify parameter regimes in which (i) a steady state is reached, (ii) the pores close at a finite time or (iii) the pores close instantaneously. An analytical expression for the time of weakening-induced pore closure is derived, which can facilitate extracting degradation kinetics from experimental data.

Keywords:

Poroelasticity Degradation Solute transport Pore closure Mathematical modelling Biomedical engineering