Contribution ID: **182**

Type: **Oral Presentation**

Multidirectional gel swelling and drying: a linear-elastic-nonlinear-swelling theory for hydrogels

Thursday, 2 June 2022 09:10 (15 minutes)

Super-absorbent polymers can form gels with polymer fractions less than 1% by volume when placed in water, with the water molecules being adsorbed by the hydrophilic polymer to form an elastic material known as a hydrogel. This water is not fixed in place: the polymer scaffold creates a porous structure through which it can flow to drive swelling and shrinking. Existing studies of the behaviour of these two-phase materials extend ideas of poro-elasticity, coupling the interstitial flow with a constitutive relation to describe the deformation stresses on the gel, or use a microscopic chemical understanding of water–polymer interactions to derive and then minimise an energy density, finding both steady and transient swelling states. In our work, we have derived both a constitutive relation and a dynamic model, expressed as a system of differential equations, which allow for nonlinearity in the swelling strains but linearise the deviatoric elastic response of the gel, in effect treating hydrogels as linear-elastic, instantaneously incompressible, materials. For one-dimensional problems, such as a gel sphere swelling in water with properties varying only in the radial direction, the swelling state can be described fully by the polymer fraction, which also determines the size of the sphere given the constraint of polymer conservation. However, in higher-dimensional problems, the polymer fraction alone cannot describe the gel, because there can be differential swelling in different directions. In such cases, we derive an equation for the displacement field for the gel, namely a modified biharmonic equation forced by the polymer-fraction field, a direct analogue of the biharmonic equation for the displacement field used in linear elasto-statics. Relying solely on the founding assumption of small deviatoric strains, we can determine the shape and composition of a gel as it swells or dries. As an illustration of the utility of this approach, we consider the problem of a cylinder with its base immersed in water while evaporating to the surrounding air. In this situation, there is both radial shrinkage and shrinkage along the axis of the cylinder, with the top of the cylinder drying to a greater extent than the base, as water is drawn up and evaporated away. Experiments have shown that the cylinder becomes concave on its top surface and convex at its base, and both of these phenomena can be described using this displacement formulation, providing further evidence of its ability to solve these more complicated problems. Furthermore, our modelling assumptions result in a description of the gel which agrees with a Lagrangian description of the drying of a cylinder as a series of stacked elastic plates which curve upwards to accommodate greater shrinkage at the top of the cylinder, providing a physically intuitive understanding of the curvature that forms.

Acceptance of the Terms & Conditions

Click here to agree

MDPI Energies Student Poster Award

No, do not submit my presenation for the student posters award.

Country

United Kingdom

References

Time Block Preference

Time Block A (09:00-12:00 CET)

Participation

Online

Primary authors: Mr WEBBER, Joseph (Institute of Theoretical Geophysics, DAMTP, University of Cambridge); Prof. WORSTER, Grae (Institute of Theoretical Geophysics, DAMTP, University of Cambridge); Dr ETZOLD, Merlin (DAMTP, University of Cambridge)

Presenter: Mr WEBBER, Joseph (Institute of Theoretical Geophysics, DAMTP, University of Cambridge)

Session Classification: MS04

Track Classification: (MS04) Swelling and shrinking porous media