Chemoelasticity with anisotropic species

Laurent Guin*[1]

[1]Laboratoire de mécanique des solides – Laboratoire de Mécanique des Solides, CNRS, Ecole Polytechnique, Institut Polytechnique de Paris – France

Abstract

Recent experiments using X-ray tomography to measure the three-dimensional strain field in rubber through have produced intriguing results (1). They show that rubber undergoes local volume changes while the overall specimen volume remains constant, and that it has an apparent negative bulk modulus. Additional radiography observations reveal the presence of a mobile phase in the material. It has been proposed that such observations can be rationalized by a chemomechanical coupling involving diffusing anisotropic species, i.e., with different eigenstrains in the different spatial directions, such as needle-like or plate-like shapes.

In this work, motivated by these new experimental results, we discuss the interplay between an isotropic linear elastic material and an anisotropic diffusing species (with initial isotropic distribution). Following a variational approach, stable equilibrium states are determined under different assumptions on the diffusivity of the species and its rotational degrees of freedom in rotation. In particular, we study the stress, deformation and concentration profiles across the cross-section of beam undergoing bending. We show that, if the species is free to rotate, then the apparent bulk modulus can only be positive, thus simply recovering the conditions set by stability on the bulk modulus of a purely elastic material. An apparent negative bulk modulus is obtained under the condition that the anisotropic species cannot rotate and, if the initial distribution of the species is isotropic, with restrictions on it its diffusion directions. In the absence of an obvious reason from the molecular structure of the material for such restrictive conditions, the explanation of such an unusual behavior remains an open question.

(1) Wang, Z., Das, S., Joshi, A., Shaikeea, A.J. and Deshpande, V.S., 2024. 3D observations provide striking findings in rubber elasticity. Proceedings of the National Academy of Sciences, 121(24).

*Speaker