Twinning and pneumatic actuation in porous elastomers

Pedro Ponte Castaneda[1] and Peter J. Caulfield*[1]

[1]Mechanical Engineering and Applied Mechanics, University of Pennsylvania – United States

Abstract

It is known that constitutive models for the large-deformation response of porous elastomers can develop "macroscopic" instabilities as a consequence of loss of strong ellipticity. Indeed, constitutive models obtained by homogenization methods for porous elastomers with periodic and random microstructures can lose strong ellipticity under appropriate loading conditions. For periodic microstructures, it has been shown theoretically, and verified experimentally and numerically, that "microscopic" instabilities consisting in solutions that are periodic on ensembles of unit cells tend to occur before the long-wavelength "macroscopic" instabilities that are captured by the loss of strong ellipticity of the homogenized response. But what about the response of porous elastomers with random microstructures? In this case, microscopic instabilities can be excluded, and the question then arises as to what happens after the onset of a macroscopic instability. Building on earlier work for reinforced elastomers, it is shown here that porous elastomers can undergo twinning after the onset of a macroscopic instability. For this purpose, use is made of a generalized Maxwell-type construction arising from the theory of relaxation and applied to linear comparison variational homogenization estimates for a certain class of two-dimensional porous elastomers consisting of aligned cylindrical pores in a rubber matrix subjected to plane strain loadings. It is shown that such porous elastomers recover Legendre-Hadamard stability by twinning after the onset of a macroscopic instability. Interestingly, the porous elastomers behave like elastic fluids in the twinned region, losing their ability to support shear stresses. Corresponding homogenization estimates for the macroscopic response when the pores are subjected to an externally applied pressure are also obtained and the implications for actuation purposes discussed.

*Speaker