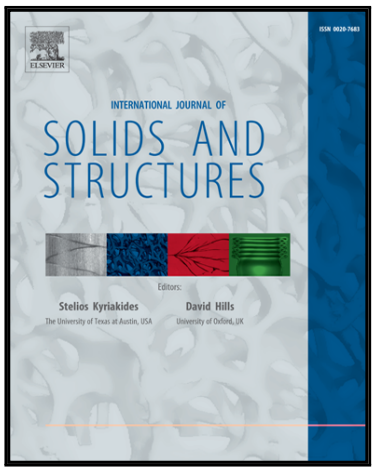

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Wrinkles in the opening angle method

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Abstract

We investigate the stability of the deformation modeled by the opening angle method, often used to give a measure of residual stresses in arteries and other biological soft tubular structures. Specifically, we study the influence of stiffness contrast, dimensions and inner pressure on the onset of wrinkles when an open sector of a soft tube, coated with a stiffer film, is bent into a full cylinder. The tube and its coating are made of isotropic, incompressible, hyperelastic materials. We provide a full analytical exposition of the governing equations and the associated boundary value problem for the large deformation and for the superimposed small-amplitude wrinkles. For illustration, we solve them numerically with a robust algorithm in the case of Mooney-Rivlin materials. We confront the results to experimental data that we collected for soft silicone sectors. We study the influence of axial stretch and inner pressure on the stability of closed-up coated tubes with material parameters comparable with those of soft biological tubes such as arteries and veins, although we do not account for anisotropy. We find that the large deformation described in the opening angle method does not always exist, as it can become unstable for certain combinations of dimensions and material parameters.

Keywords: opening angle method, large bending, nonlinear elasticity, bifurcation, coated sector, soft tissue modeling.

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