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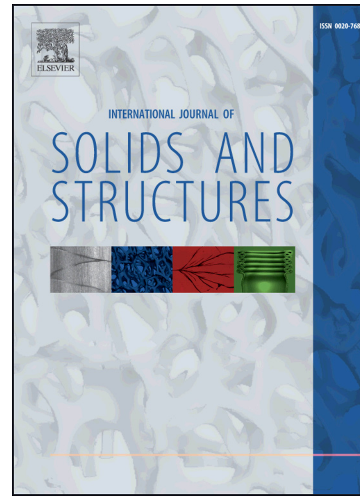

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Inflating a Flat Toroidal Membrane

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Abstract

A flat toroidal geometry, composed of a stack of two flat annular membranes bonded together at the inner and outer boundaries (equators), is proposed. The finite inflation mechanics of the composite membrane under uniform internal pressure is considered. The membranes are assumed to be identical homogeneous and isotropic solids described by the Gent hyperelastic model with a relaxed strain energy density function. The variational inflation mechanics problem yields the governing equations and boundary conditions, which are recast as a nonlinear two-point boundary value problem in a suitable form for efficient computation. The effects of the inflation pressure and material properties on the state of stretch and geometry of the inflated toroidal membrane are obtained, which exhibit a number of desirable features. The phenomenon of wrinkling instability is observed near the outer equator of the torus at low pressures (in spite of a positive Gaussian curvature), which is exactly opposite to the behaviour observed in a curved torus (wrinkling at the inner equator at high pressure). Semi-analytical expressions of the Cauchy stress resultants are obtained which match well with the numerical computations. Further, the limit-point instability pressure of the toroidal membrane is shown to have a remarkable power-law dependence on a geometric parameter of the uninflated flat torus and the material chain extensibility parameter involving two universal constants.

Keywords: Finite inflation, Flat torus, Gent model, Relaxed strain energy density function, Wrinkling, Limit-point pressure

1 Introduction

Inflatable structures are preferable in several applications as they are light, can be packed/stowed and deployed quickly when required, and are cost competitive. The use of inflatables in scientific ballooning, tires and air-bags is not new. Modern applications include inflatable

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