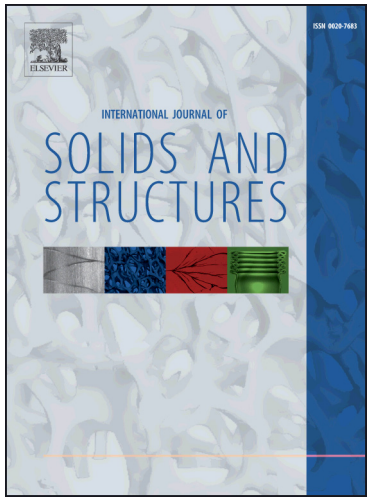

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Contact Mechanics of a Circular Membrane Inflated against a Deformable Substrate

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Abstract

Finite inflation of a hyperelastic flat circular membrane against a deformable adhesive substrate and peeling upon deflation are analyzed. The membrane material is considered to be a homogeneous, isotropic and incompressible Mooney-Rivlin solid. The deformable substrate is assumed to be a distributed linear stiffness in the direction normal to the undeformed surface. The adhesive contact is considered to be perfectly sticking with no tangential slip between the dry surfaces of the membrane and the substrate. The inflation mechanics problem in the variational form yields the governing equations and boundary conditions, which are transformed to a nonlinear two-point boundary value problem by a careful choice of field variables for efficient computation. It is found that during inflation (deflation) with adhesive contact, the meridional stretch exhibits continuity up to $\mathcal{C}^0$ ($\mathcal{C}^{-1}$) at the contact junction, while the circumferential stretch remains continuous up to $\mathcal{C}^1$ ($\mathcal{C}^0$). Interestingly, stretch locking in an adhesive contact is found to give a higher indentation on the substrate than in a frictionless contact. Peeling at the contact junction has been studied, and numerical formulations for the energy release rate are proposed.

Keywords: Constrained inflation, Deformable substrate, Adhesive contact, Contact peeling, Energy release rate.

1. Introduction

The problem of contact between an inflated membrane and an elastic surface appears in different contexts in a number of scientific studies and technological applications. The problem is relevant to, for example, contact of cells within themselves or with a deformable substrate, estimation of mechanical properties of bilayer membranes from contact interaction mechanics, contact of an inflated balloon with walls of arteries in balloon angioplasty, and constrained inflation in certain manufacturing processes (Charrier et al., 1987; Evans and Needham, 1987; Khayat and Derdouri, 1994; Pamp and Adams, 2007; Tsang et al., 2006; Wan and Liu, 2001). The contact in a large number of such cases is adhesive in nature. Understanding the stress distribution, deformation at the contacting surfaces, and stability and peeling of a membrane are some of the important issues in such problems. Here, we focus on the contact problem in an elastomeric membrane finitely inflated against a deformable adhesive substrate.

The theory of large deformation during inflation of elastomeric membranes was founded in the works of Mooney (1940) and Rivlin (1948). Subsequently, a number of important advances in the theory of

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