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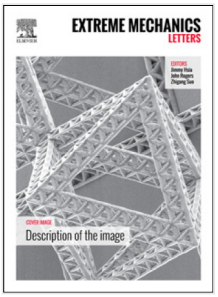

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Post-wrinkle bifurcations in elastic bilayers with modest contrast in modulus

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Abstract

Wrinkles, folds, creases and other elastic surface instabilities play a crucial role in many systems in nature and engineering. While surface instabilities of ideal bilayer structures with large contrasts in elastic stiffness are well understood, many natural and man-made structures are far from this ideal. To better understand the behavior of systems with modest stiffness contrast, in particular their secondary post-wrinkling bifurcations, we systematically vary the modulus contrast between the film and the substrate through a combination of experiments and finite element simulations. Above a modulus contrast of about 2, but below approximately 14, wrinkles represent the primary bifurcation mode, but can undergo two distinct types of secondary bifurcations upon further compression: (1) a direct transition from wrinkles to creases, and (2) wrinkles that first undergo period doubling, followed by a transition to creases.

Introduction

Surface buckling instabilities are observed in everyday life, from wrinkles on skin to folds in the brain. Such processes arise when an elastic material is compressed beyond a critical strain either by swelling, differential growth, or mechanical forces. In engineering, similar instabilities have long been thought of as nuisances, but they have recently found applications in many different contexts including flexible electronic devices[1–4], surface patterning methods[5–8] and materials with tunable optical properties[9–12], adhesion[13–15], and wettability[9,16,17].

In biological systems, many tissues and organs are composed of multilayers with similar moduli, which may undergo a variety of buckling instabilities during growth or deformation.[18–23] Thus, understanding the buckling behavior of multilayers with a modest contrast in elastic modulus may provide insight into pattern formation in such systems. However, most studies have focused on bilayers with a much stiffer thin film on top of a compliant thick substrate,[24–

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