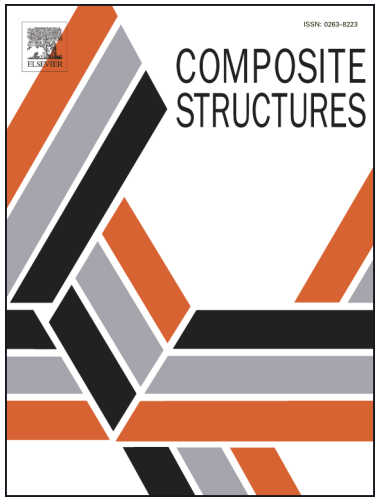

Semi-analytical isogeometric analysis for wrinkling instability of stiff films bonded to cylindrical modulus-graded compliant substrates

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Semi-analytical isogeometric analysis for wrinkling instability of stiff films bonded to cylindrical modulus-graded compliant substrates

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Abstract

Surface wrinkles in film-substrate structures have received considerable attention in science and engineering. Understanding the wrinkling instability is the key to envisioned applications of these structures. In this paper, based on Floquet's principle, an explicit semi-analytical isogeometric analysis method (SIGA) is proposed for predicting wrinkling instability of a stiff film on cylindrical graded substrate. In total Lagrangian framework, the wrinkle configuration is considered as the stressed state relative to the stress-free state. The linearized variational formulation with respect to stress (wrinkle) is derived from the principle of minimum potential energy and parameterized by non-uniform rational basis splines (NURBS). By using the SIGA method, only the radial direction of layered structure is parameterized and the dimension of model is reduced to the one-dimensional. Meanwhile, the analysis of wrinkling instability can be performed by a generalized eigenvalue problem, which explicitly determines critical wrinkling strain and wavelength. Compared to the finite element method, the proposed approach demonstrates distinct superior in computational efficiency and accuracy. Besides, two typical functions are employed to describe material distribution of inhomogeneous substrate. The critical conditions for wrinkling instability of the film-substrate system are computed and the influences of various geometric and material parameters are discussed in detail.

Keywords:

Semi-analytical isogeometric analysis; wrinkle; film-substrate; graded material; cylindrical structures

1. Introduction

Film-substrate systems are ubiquitious in nature and engineering applications [1–3], by reasons of the factors such as the fabrication and use of thin film devices , the growth of biological tissues and the physical stimulation, a compressing stress is produced to be beyond the critical value in the thin film, which may leads to the onset of wrinkling instability. As a typical case of instability, wrinkle is not only a failure mode avoided in most engineering designs [4] but also a useful mechanical

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