Impact of Input Uncertainty on Film Delamination Driven by Thermal Induced Instability

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The buckling-driven delamination of thin films bonded to rigid substrates is a well-known phenomenon that occurs when an initially debonded and compressed region tends to buckle and further debond. Thin films bonded to rigid surfaces are found in many engineering applications such as optical surface coatings, thermal barier coatings, electronics, composite materials, and others. The literature of the last four decades reflects an extensive investigation of such different forms. Two differrent approaches can be identified in the literature for the analysis of this problem: A fracture mechanics approach and a cohesive interface approach. Many analytical and numerical works that analyse the two nonlinear conjugated phenomena involved in the process, namely the geometrical nonlinearity (buckling) and the interfacial one (delamination) are found in the literature. In addition, many experimental observations on the geometry of the buckling-driven delamination, including straight-sided blisters, circular blisters, telephone cord blisters, and wrinkling, are found. These observations indicate that buckling-driven delamination is a highly unstable process that involves the evolution of two coupled and highly nonlinear mechanisms. It is therefore expected to be very sensitive to variations and to uncertainty of the structural parameters which define the problem. To the best of the authors' knowladge, the question of input uncertainty and its impact on the uncertain nonlinear and unstable response of the strucutre were never considered. The present work is concerned with the consideration of input uncertainty in the response of a thin film that undergoes a thermaly induced, 1D buckling-driven delamination and with the quantitative assessment of its impact. A simplified 1D model in which the film strip is modeled as a Bernoulli-Euler beam and the bonding surface is represented by a cohesive interface is developed. The quasi-static response of the strongly nonlinear anlytical model is numerically solved by means of a specially tailored 1D Finite Element formulation and by a degenerated dynamic analysis. The stochastic analysis is conducted by the perturbation-based Stochastic Finite Elelements Method and where possible it is compared with the results of a Monte-Carlo simulation for validation. The results reveal and quantify the impact of input uncertainty on the film's structural response and show that the perturbation-based SFEM is capable of describing the stochastic response of the film with direct implication on the functionality of the system.