Post-buckling of fiber-reinforced materials

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Abstract

Many biological tissues are fiber-reinforced, enhancing their physical properties and exhibiting inherent anisotropy. The interplay of fiber stiffness, fiber orientation, and the elastic properties of the matrix on pattern formation and evolution in layered tissues still requires a comprehensive understanding. We consider a paradigmatic model with a film coated to a half-space where either the film or the substrate is anisotropic. In particular, the Holzapfel-Gasser-Ogden model is used to capture fiber-reinforcements. To investigate post-buckling evolution, a weakly nonlinear analysis is performed to derive an amplitude equation applicable to both scenarios. A detailed parametric study unravels the effects of fiber orientation, fiber stiffness, and modulus ratio on the post-buckling solution. When the film is fiber-reinforced, it turns out that the bifurcation will always be supercritical if r$<$ 0.571 where r is the ratio of the shear modulus of the substrate to that of the film. We further identify an additional condition under which subcritical bifurcations can emerge. If the substrate is fiber-reinforced, the integrated impact of material anisotropy becomes more complicated. Finally, we explore from our post-buckling solution where the fibers first experience compression and also plot the bifurcation diagram from which the evolution of the wrinkled amplitude is depicted. These analytical post-buckling solutions offer valuable insights into the morphological development of biological tissues.

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