Periodic bulging in the elastic Rayleigh-Plateau instability

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Abstract

Experiments reveal that surface tension can destabilize soft elastic cylinders, resulting in a periodic series of bulges along their length. This instability represents the elastic analog of the Rayleigh-Plateau instability in fluids. Traditional elastocapillary models typically assume a constant surface tension, predicting a single isolated bulge. However, this prediction contrasts with experimental observations, which show multiple periodic bulging. An important distinction in elastic materials is that surface tension is strain-dependent, a phenomenon known as the Shuttleworth effect. In this talk, we demonstrate that the use of a strain-dependent surface tension accurately predicts a buckled morphology with a finite critical wavelength. Our approach models surface tension as the behavior of a pre-stretched elastic surface, following the framework proposed by Gurtin and Murdoch. When linearized for small strains, this model reduces to Shuttleworth's equation. We complement our theoretical analysis with numerical simulations, which provide insight into how mechanical properties and an applied axial stretch influence the wavelength and shape of the resulting periodic structure.

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