Parametric excitation of rotating modes

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Abstract

In the present study, we explore the existence and the characteristics of a rotating mode for elastic systems with an axially symmetric potential exhibiting a zero energy mode. For such systems the equilibrium configuration can rotate continuously around the axis of symmetry of the underlying potential field at no energy expense. The simplest system showing this behavior is an underdetermined mass-spring system with one end of the spring pinned and allowed to rotate freely. Elastic systems of this class, show an induced near-zero energy rotating mode for the case that the oscillator is driven by a harmonic force in the radial direction. The rotational oscillations can be excited when introducing a perturbation in the underlying potential field such that the axial symmetry is broken. A theoretical study of the induced rotation shows that the behavior of this system is governed by the physics of a parametric oscillator that leads to parametric instability. Indeed two nondimensional parameters dictate the stability of the trivial limit cycle for which there is no rotation. More complex systems, as is a network of masses connected with springs can also exhibit rotating modes when excited by a force perpendicular to the plane. In the case of continuous systems, zero energy modes can appear when certain conditions are met. As an example, an elastic circular disk with imposed internal stresses can buckle and the resultant deformation field can freely rotate around the axis of symmetry of the internal stresses. The rotation of this mode can be controlled by an imposed vibration in the direction perpendicular to the flat disk without inducing any angular momentum. Elastic systems with a rotating vibration mode can be used in applications such as actuation and transmission of rotary motion and more.
Acknowledgments. PK and MR gratefully acknowledge funding from the National Science Foundation (NSF) under the grant "Collaborative Research: Design and Reconfiguration of Curved Surfaces for Targeted Wave Propagation" with award number 224709.

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