Escape Dynamics of a Particle From a Purely-nonlinear Truncated Quartic Potential Well Under Harmonic Excitation

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Research Article

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Abstract

This paper focuses on the escape problem of a harmonically-forced classical particle from a purely-quartic truncated potential well. The latter corresponds to various engineering systems that involve purely cubic restoring force and absence of linear stiffness even under the assumption of small oscillations, such as pre-tensioned metal wires and springs, and compliant structural components made of polymer materials. This, in contrast to previous studies

where the equivalent potential well could be treated as linear at first approximation under the assumption of small perturbations. Due to the strong nonlinearity of the current potential well, traditional analytical methods are inapplicable for describing the transient bounded and escape dynamics of the particle. The latter is analyzed in the framework of isolated resonance approximation by canonical transformation to action-angle (AA) variables and the

corresponding reduced resonance manifold (RM). The escape envelope is formulated analytically. Surprisingly, despite the essential nonlinearity of the well investigated, it exhibits a universal property of a sharp minimum due to the existence of multiple intersecting escape mechanisms. Unlike previous studies, three underlying mechanisms that govern the transient dynamics of the particle were identified: two maximum mechanisms and a saddle mechanism. The first two correspond to a gradual increase in the system's response amplitude for a proportional increase in the excitation intensity, and the latter corresponds to an abrupt increase in the system's response and therefore more potentially hazardous. The response of the particle is described in terms of energy-based response curves. The maximal transient energy is predicted analytically over the space of excitation parameters and described using iso-energy contours. All theoretical predictions are in complete agreement with numerical results.

Full-text

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Figures

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