Vibration localization and snaking phenomenon in friction-excited cyclic symmetric oscillators chains

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Abstract

In different physics fields spatially localized states have been encountered. Examples can be found in granular matter [1], optics [2], fluid dynamics [3] and structural mechanics [4]. In particular in fluid dynamics localized convective rolls have been observed in water-ethanol mixture [3] or helium [5]. These spatially localized states arrange in the bifurcation diagram in a peculiar way: two snaking trajectories entwine each other linking localized solutions at different energy levels and giving birth to the classical snaking picture. Here the mechanical behavior of a cyclic symmetric chain of nonlinear oscillators is studied. The springs are linear, while a polynomial form of degree five is used to model the damping force which depends on velocity. The linear damping term stabilize the small vibrations, the cubic term pumps energy into the system while a dissipative quintic term stabilizes the vibrations for large amplitudes. Self-excited vibrations are triggered via initial conditions and the system dynamics is studied. The system energy is plotted against the bifurcation parameter ξ_1, i.e. the linear term of the damping law. The steady-state solution is approximated with one harmonic using the harmonic balance method [6], and the algebraic system of equations is solved with a Newthon-Raphson scheme. A pseudo arc-length continuation algorithm [6] is implemented to follow the system trajectories. Multiple localized solutions were found that superposed in the bifurcation diagram give birth to a structure which strongly resembles the snaking picture observed in the above-mentioned physics fields. At the best of the authors knowledge a similar structure has never been studied in the mechanical vibration framework. A detailed analysis of the vibration shape and of the energy content of the localized solutions is conducted to show similarities and differences with the classical snaking phenomenon.

Keywords: snaking bifurcation, localized vibration, nonlinear vibrations, subcritical Hopf bifurcation, Harmonic Balance Method (HBM)

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