Complex Dynamics of a Bistable Asymmetric Laminated Composite Square Panel

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Abstract. The global bifurcations and multi-pulse chaotic motions of a bistable asymmetric laminated composite square panel under the foundation excitation are studied. Then, the energy-phase method is utilized to analyze the complex dynamics of the panel. The analytical results show that there exist Shilnikov type multi-pulse jumping orbits for the resonant case homoclinic to certain invariant sets in Hamiltonian perturbations which lead to chaos in the bistable panel system. The numerical results demonstrate that the Shilinikov multi-pulse jumping chaotic and small metastable chaotic vibrations coexist in the bistable asymmetric laminated composite square panel. It is found that the external excitation changes the complexity of the chaos, while the parameter excitation changes the type of the chaos.

Introduction

The composite structures with two different stable state equilibrium positions are called as the bistable composite structures, such as the asymmetrically laid laminated composite plates and panels [1] and anti-symmetric laid laminated composite cylindrical and shallow shells [2]. The bistable asymmetric composite laminated panel has two stable-state vibrations located in the upper-mode or lower-mode around an unstable equilibrium position at the middle location, which are regarded as the upper-mode and lower-mode vibrations. Because of their excellent mechanical properties, the bistable asymmetric laminated composite square panels are being potentially used in aerospace [3], morphing structure [4], energy harvesting [5], electronic devices and other special fields [6].

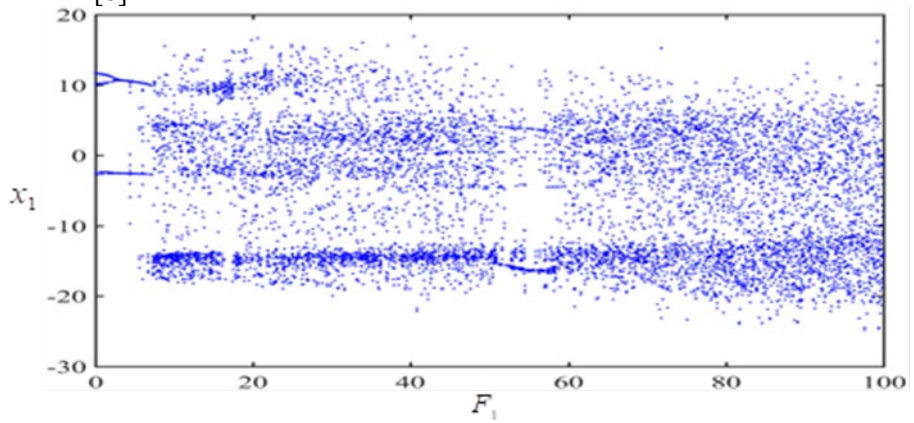

Figure 1: Two-dimensional bifurcation diagrams for the bistable asymmetric laminated composite square panel

From Figure 1, it is found that the periodic to chaotic vibrations alternately happen in the first-order mode of the bistable asymmetric composite laminated square panel. The occurrence of the chaotic vibrations are mainly concentrated on the intervals [0,5] and [50,60], as shown in Figure 1. The metastable chaos mainly occur in the intervals [10,50] and [60,100] for the first-order vibration mode. It is observed that there exist the periodic vibrations when the amplitudes of the parametric excitations are small in the first-order mode. We also know that the periodic and double excitation Shilinikov multi-pulse jumping chaotic vibrations occur alternately with the increase of the parametric excitations .

References

[1] W. Zhang, Y. Z. Liu and M. Q. Wu, Theory and experiment of nonlinear vibrations and dynamic snap-through phenomena for bi-stable asymmetric laminated composite square panels under foundation excitation, Composite Structures 225, p111140.1-111140.18, 2019.

[2] Z. Zhang, H. L. Wu, X. Q. He, H. P. Wu, Y. M. Bao and G. Z. Chai, The bistable behaviors of carbon-fiber/epoxy anti-symmetric composite shells, Composites: Part B 47, p190-199, 2013.

[3] F. Mattioni, P. M. Weaver, K. D. Potter and M. I. Friswell, The application of thermally induced multistable composites to morphing aircraft structures, Proceeding of SPIE 6930, 693012-11, 2008.

[4] S. W. Kim, J. S. Koh, M. H. Cho and K. J. Cho, Soft morphing motion of flytrap robot using bending propagating actuation, Journal of Institute of Control, Robotics and Systems 18, p168–174, 2012.

[5] A. F. Arrieta, P. Hagedorn, A. Erturk and D. J. Inman, A piezoelectric bistable plate for nonlinear broadband energy harvesting, Applied Physics Letters 97, 104102, 2010.

[6] W. R. Dichtel, J. R. Heath and J. F. Stiddart, Designing bistable rotaxanes for molecular electronic devices, Philosophical Transactions, Mathematical, Physical, and Engineering Sciences 365, p1607-1625, 2007.