CHAOS 2009

2nd Chaotic Modeling and Simulation International Conference

June 1 - 5, 2009 Chania Crete Greece www.chaos2009.net

Chaotic Vibrations of Circular Cylindrical Shells: Galerkin Versus redused-order Models

M. Amabili, M. P. Païdoussis

Department of Mechanical Engineering, McGill University, Montreal, Canada

The response of water-filled, geometrically nonlinear simply supported circular cylindrical shells to harmonic excitation in the spectral neighbourhood of the fundamental natural frequency is investigated. The response is investigated for a fixed excitation frequency by using the excitation amplitude as bifurcation parameter for a wide range of variation. Bifurcation diagrams of Poincaré maps obtained from direct time integration and calculation of the Lyapunov exponents and Lyapunov dimension have been used to study the system. By increasing the excitation amplitude, the response undergoes (i) a period-doubling bifurcation, (ii) subharmonic response, (iii) quasi-periodic response and (iv) chaotic behaviour with up to 16 positive Lyapunov exponents (hyperchaos). The model is based on Donnell's nonlinear shallow-shell theory, and the reference solution is obtained by the Galerkin method. The proper orthogonal decomposition (POD) method is used to extract proper orthogonal modes that describe the system behaviour from time-series response data. These time-series have been obtained via the conventional Galerkin approach (using normal modes as a projection basis) with an accurate model involving 16 degrees of freedom (dofs), validated in previous studies. The POD method, in conjunction with the Galerkin approach, permits building a lower-dimensional model as compared to those obtainable via the conventional Galerkin approach. Periodic and quasi-periodic response around the fundamental resonance for fixed excitation amplitude can be very successfully simulated with a 3-dof reduced-order model. However, in the case of large variations of the excitation, even a 5-dof reduced-order model is not fully accurate.

REFERENCES

1) M. Amabili, 2008, Nonlinear Vibrations and Stability of Shells and Plates, Cambridge University Press, New York, USA.

2) M. Amabili, A. Sarkar and M. P. Païdoussis, 2006, Journal of Sound and Vibration, Vol. 290, No. 3-5, pp. 736-762. Chaotic vibrations of circular cylindrical shells: Galerkin versus reduced-order models via the proper orthogonal decomposition method.

3) M. Amabili and C. Touzé, 2007, Journal of Fluids and Structures, Vol. 23, pp. 885-903. Reduced-order models for nonlinear vibrations of fluid-filled circular cylindrical shells: Comparison of POD and asymptotic nonlinear normal modes methods.

4) S. A. Zahorian, M. Rothenberg, Principal component analysis for low-redundancy encoding of speech spectra. Journal of the Acoustical Society of America 69 (1981) 519-524.

5) L. Sirovich, Turbulence and dynamics of coherent structures, Part I: coherent structures. Quarterly of Applied Mathematics 45 (1987) 561-571.

6) M. F. Azeez, A. F. Vakakis, Proper orthogonal decomposition (POD) of a class of vibroimpact oscillations. Journal of Sound and Vibration 240 (2001) 859-889.

7) G. Kerschen, B. F. Feeny, J.-C. Golinval, On the exploitation of chaos to build reduced-order models. Computer Methods in Applied Mechanics and Engineering 192 (2003) 1785-1795.