DYNAMICAL SYSTEMS WITH PERIODIC COEFFICIENTS: ANALYSIS AND CONTROL

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Abstract

A general framework for the analysis and control of parametrically excited linear/nonlinear dynamical systems is presented. This class of problems appears in the modeling of rotorcraft blades in forward flight, asymmetric rotor-bearing systems, automotive components such as connecting rods, universal joints, asymmetric satellites, fluids under gravity modulations, etc. These dynamical systems are represented by a set of differential equations which contain time-periodic coefficients. First, an efficient computational scheme for the solution of linear problem is discussed through an application of Chebyshev polynomials. The idea is further developed to obtain the Lyapunov-Floquet (L-F) transformation associated with a linearized or a quasilinear time-periodic dynamical system. An application of L-F transformation yields equivalent systems whose linear parts are time-invariant. Therefore, the controls for all time-periodic linear systems can be designed using the standard time-invariant methods such as pole placement or optimal control theory. A symbolic control technique for Floquet multiplier placement is also suggested for linear time-periodic systems. In the case of nonlinear systems, a periodic orbit in the original coordinates has a fixed point representation after the L-F transformation. The local stability and bifurcation analyses are studied via time-dependent center manifold reduction and normal form theory. Results for fold, flip and secondary Hopf bifurcations are discussed. Bifurcation control and feedback linearization techniques for nonlinear time-periodic systems are also developed and applied to some typical problems. Further, the order reduction problem associated with free and forced parametrically excited large-scale nonlinear systems is also addressed using an invariant manifold approach. A methodology for reduced order controller design is also suggested. The practical significance of these approaches is demonstrated through simulations and experimental investigations of a number of mechanical systems. These include vibration control of a multi-bladed rotor, shafts supported by magnetic bearings, bifurcation analyses of flexible slider crank mechanism and an autoparametric mechanical system, among others.