Nonlinear Dynamics for a Time Delayed Rijke Tube System with Periodic Excitation

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Abstract

Thermoacoustic instability problems widely exist in many real-world applications such as gas turbines and rocket motors. A Rijke tube is a typical thermoacoustic system, and it is difficult to analyze such a system due to the nonlinearity and time delay. In this paper, a set of nonlinear ordinary differential equations with time delay which represent a Rijke tube system will be studied. The state space of such a tube system consists of velocity and pressure, and the periodic motion can be discretized based on an implicit midpoint scheme. Through Newton–Raphson method, the node points on the periodic motion will be solved, and the analytical solution of such a periodic motion for Rijke tube system can be recovered using a set of Fourier representations. According to the theory of discrete maps, the stability of the periodic motion will be obtained. With such a proposed technique, the stable and unstable branches of period-1 motions with one mode and multiple modes will be presented. The Neimark–Sacker bifurcation will be observed, and the periodic and quasi-periodic motions related to Neimark–Sacker bifurcation will be discussed. The strange dynamic behavior for stable period-1 motion at the neighborhood of Neimark–Sacker bifurcation will be observed, and the motion can only be attracted to the stable period-1 limit cycle when the initial conditions are given exactly from the analytic solution of such a stable period-1 motion. Otherwise, it will be attracted to another coexisting quasi-periodic motion.

Keywords: Thermoacoustic, Periodic motions, Chaos, Semianalytic, Bifurcation

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