ABSTRACT

The subject of pipes conveying fluid has widespread domestic and industrial applications. It has proven to be a vital area of mechanics. It can be studied both theoritically and with experiments and constitutes a fluid-structure interaction problem of self excited nature. It is subject to fluidelastic instabilities viz. divergence and flutter depending on the characteristic of the structure and the flow. It can also be parametrically excited through pulsation in fluid flow. These flow-induced instabilities, in addition to being of practical concern, are of immense fundamental interest. The pipes conveying fluid also exhibit a wide range of linear and nonlinear dynamic behaviour depending on the system parameters and the operating conditions. Nonlinear modal interaction in the form of internal resonance can also influence the system behavior. In the present work, the nonlinear dynamics of hinged-hinged and hinged clamped pipes have been studied for parametric and combination resonances in presence of two mode internal resonance. Also two frequency parametric excitation is considered. In these studies, direct perturbation MMS technique is adopted for the analysis. Nonlinear dynamics of a cantilevered pipe is also studied parametrically.

In the study on parametric and combination resonances of hinged-hinged and hinged clamped pipes in presence of 3:1 internal resonance, new zones of instability besides the main instability zone are found in the trivial state stability plots attributed to internal resonance. These new instability zones result in additional bifurcations in the frequency and amplitude response curves which have supercritical and subcritical pitchfork, saddle node and Hopf bifurcations. For combination parametric resonances, isolated two mode solutions are observed in the frequency and amplitude response plots, whereas for the case of principal parametric resonances of second mode, single-mode and two mode responses are observed. Periodic, quasiperiodic and chaotic responses are observed in the system for variation of the control parameters like amplitude and frequency detuning parameter of the flow fluctuation. Jump and saturation phenomena are also observed. The route to chaos is through quasiperiodicity.

In the case of two frequency parametric excitations, simultaneous principal and combination parametric resonances are studied. Additional zones of instability in trivial state stability plots due to internal resonance and the second component of flow pulsation are observed. The resulting frequency and amplitude response curves become more complicated with additional bifurcation points. This wide range of dynamic solutions viz. periodic, quasiperiodic and chaotic response are observed. The system exhibits mixed mode oscillations, beating oscillations, jump and saturation phenomena for variation of control parameters.

The cantilevered pipe system is parametrically studied through numerical simulation by multimode discretization and Galerkins method to illustrate the combined influence of lumped mass, linear and nonlinear elastic constraints besides other parameters. A wide spectrum of dynamic behavior is observed. The principal route to chaos is through cascade of period-doubling.

Key words : Pipe, fluid, nonlinear dynamics, pulsatile flow, parametric excitation, parametric resonance, internal resonance, periodic, quasiperiodic, chaos, perturbation method, trivial stability, frequency response, amplitude response, period-doubling, mixed mode oscillation.