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Semi-active stabilization of pipe discharging air with electromagnetic devices of motional type

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Abstract

The study deals with a problem of applying electromagnetic devices of motional type [1] to improve the dynamic stability of a pipe conveying air. When the flow velocity reaches its critical value the steady equilibrium position becomes unstable, and self-excited lateral vibrations arise. Electromagnetic devices of another – transformer – type demonstrated to have been highly effective in passive stabilization of such system [2] as well as active stabilization of similar non-conservative system with a follower force [3]. In the present work, we apply a pair of motional devices made of a conducting plate which is attached to the pipe and moves together with it within the perpendicular magnetic field generated by the controlled electromagnets. This motion generates eddy currents in the plates and a drag force of a viscous character. Under this setting, we firstly investigate the possibility of designing a stabilizing control within the magnetic field's region where every passive solution results in an unstable or conservative state. For that purpose, we constitute a practical condition justifying the existence of a stabilizing control for a given set of system parameters. Later we pose and solve an optimal control problem aiming at stabilizing the system with the optimal rates of decrease of the system's energy. The solution is examined by means of numerical simulations performed within the three regions of the flow velocity: low subcritical where the Coriolis acceleration of the conveyed fluid generates the predominate damping force, high subcritical where the inertia of the fluid begins to dominate dynamics of the system, and low supercritical where unstable flutter vibrations start to arise. The effectiveness of the designed optimal controller is validated by comparisons with the corresponding passive solutions.

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