Aeroelastic Analysis of Nonlinear All-Movable Fin with Freeplay in Low-Speed

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Abstract : Aerospace systems, generally speaking, are inherently nonlinear. These nonlinearities may modify the behavior of the system. However, nonlinearities in an aeroelastic system can be divided into structural and aerodynamic. Structural nonlinearities can be subdivided into distributed and concentrated ones. Distributed nonlinearities are spread over the whole structure representing the characteristic of materials and large motions. Concentrated nonlinearities act locally, representing loose of attachments, worn hinges of control surfaces, and the presence of external stores. The concentrated nonlinearities can be approximated by one of the classical structural nonlinearities, namely, cubic, free-play and hysteresis, or by a combination of these, for example, a free-play and a cubic one. Compressibility, aerodynamic heating, separated flows and turbulence effects are important aspects that result in nonlinear aerodynamic behavior. An issue related to the low-speed flutter and its catastrophic/benign character represented by Limit Cycle Oscillation (LCO) of all-movable fin, as well to their control is addressed in the present work. To the approach of this issue: (1) Quasi-Steady (QS) Theory and Computational Fluid Dynamics (CFD) of subsonic flow are implemented, (2) Flutter motion equations of a two-dimensional typical section with cubic nonlinear stiffness in the pitching direction and free play gap are established, (3) Uncoupled bending/torsion frequencies of the selected fin are computed using recently developed Transfer Matrix Method of Multibody System Dynamics (MSTMM), and (4) Time simulations are carried out to study the bifurcation behavior of the aeroelastic system. The main objective of this study is to investigate how the LCO and chaotic behavior are influenced by the coupled aeroelastic nonlinearities and intend to implement a control capability enabling one to control both the flutter boundary and its character. By this way, it may expand the operational envelop of the aerospace vehicle without failure.

Keywords : aeroelasticity, CFD, MSTMM, flutter, freeplay, fin
Conference Title : ICCFD 2017 : International Conference on Computational Fluid Dynamics
Conference Location : London, United Kingdom
Conference Dates : October 19-20, 2017