Mechanical Engineering Master's Defense

The Effects of Nonlinear Damping on Post-flutter Behavior Using Geometrically Nonlinear Reduced Order Modeling

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abstract

Recent studies of the occurrence of post-flutter limit cycle oscillations (LCO) of the F-16 have provided good support to the long-standing hypothesis that this phenomenon involves a nonlinear structural damping. A potential mechanism for the appearance of nonlinearity in the damping are the nonlinear geometric effects that arise when the deformations become large enough to exceed the linear regime. In this light, the focus of this investigation is first on extending nonlinear reduced order modeling (ROM) methods to include viscoelasticity which is introduced here through a linear Kelvin-Voigt model in the undeformed configuration. Proceeding with a Galerkin approach, the ROM governing equations of motion are obtained and are found to be of a generalized van der Pol-Duffing form with parameters depending on the structure and the chosen basis functions. An identification approach of the nonlinear damping parameters is next proposed which is applicable to structures modeled within commercial finite element software.

The effects of this nonlinear damping mechanism on the post-flutter response is next analyzed on the Goland wing through time-marching of the aeroelastic equations comprising a rational fraction approximation of the linear aerodynamic forces. It is indeed found that the nonlinearity in the damping can stabilize the unstable aerodynamics and lead to finite amplitude limit cycle oscillations even when the stiffness related nonlinear geometric effects are neglected. The incorporation of these latter effects in the model is found to further decrease the amplitude of LCO even though the dominant bending motions do not seem to stiffen as the level of displacements is increased in static analyses.

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