Numerical Simulations of Interactions Among Aerodynamics, Structural Dynamics, and Control Systems

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(ABSTRACT)

A robust technique for performing numerical simulations of nonlinear unsteady aeroelastic behavior is developed. The technique is applied to long-span bridges and the wing of a modern business jet. The heart of the procedure is combining the aerodynamic and structural models. The aerodynamic model is a general unsteady vortex-lattice method. The structural model for the bridges is a rigid roadbed supported by linear and torsional springs. For the aircraft wing, the structural model is a cantilever beam with rigid masses attached at various positions along the span; it was generated with the NASTRAN program. The structure, flowing air, and control devices are considered to be the elements of a single dynamic system. All the governing equations are integrated simultaneously and interactively in the time domain; a predictor-corrector method was adapted to perform this integration.

For long-span bridges, the simulation predicts the onset of flutter accurately, and the numerical results strongly suggest that an actively controlled wing attached below the roadbed can easily suppress the wind-excited oscillations. The governing equations for a proposed passive system were developed.

The wing structure is modelled with finite elements. The deflections are expressed as an expansion in terms of the free-vibration modes. The time-dependent coefficients are the generalized coordinates of the entire dynamic system. The concept of virtual work was extended to develop a method to transfer the aerodynamic loads to the structural nodes. Depending on the speed of the aircraft, the numerical results show damped responses to initial disturbances (although there are no viscous terms in either the aerodynamic or structural model), merging of modal frequencies, the development of limit-cycle oscillations, and the occurrence of a supercritical Hopf bifurcation leading to motion on a torus.

To my past, Arón. To my present, Sandra. To my future, Julia and David.

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