NONLINEAR DYNAMICS OF VERY HIGH DIMENSIONAL FLUID-STRUCTURAL SYSTEMS

Earl H. Dowell
J. A. Jones Professor
Department of Mechanical Engineering and Materials Science
School of Engineering
Duke University

The dynamics of mechanical systems of high dimension or many degrees of freedom will be discussed. The modeling of both fluid and structural systems will be considered with special emphasis given to fluid-structural or aeroelastic systems. Novel and effective theoretical and computational techniques will be considered and illustrative correlations with experimental results given. Also briefly considered will be nanoscale systems that are modeled at the molecular level using similar mathematical techniques.

Aeroelastic systems are those that involved the coupled interaction between a convecting fluid flow and a flexible elastic structure. The nonlinear dynamical response of such systems is of great current interest. Currently operational aircraft are known to encounter limit cycle oscillations (LCO) in certain flight regimes and relatively simple experimental wind tunnel models have been designed to exhibit LCO as well. The LCO may be either beneficial or dangerous for the safely of the aircraft. The results of several wind tunnel experiments are discussed and compared to those from mathematical models. The physical models include (1) an airfoil with control surface freeplay; (2) a delta wing with structural geometrical nonlinearities due to plate-like deformations; and (3) a very high aspect ratio wing with geometrical structural nonlinearities due to coupling among torsional twist, transverse bending and fore-and-aft bending. In addition, the theoretical and computational advantages of modeling the aerodynamic flow field in terms of a set of global modes and also using a novel form of the harmonic balance method are emphasized. A recent theoretical result for large shock motions in a viscous transonic flow around an oscillating airfoil undergoing LCO is presented to illustrate the results to be obtained by such methods.