FLAPPING WING DYNAMICS OF MAVs: NONLINEAR MODELING AND EXPERIMENTAL INVESTIGATION

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ABSTRACT

Analysis of the flapping-wing motion of micro air vehicles (MAVs) is a complex problem that involves nonlinear structural analysis coupled with unsteady fluid mechanics analysis. In this study I apply a fully nonlinear finite element modeling code for simulation of large-amplitude flapping motions. The MAV wing is modeled using fully nonlinear beam and membrane elements based on geometrically exact total-Lagrangian beam and membrane theories, and the unsteady aerodynamic loads are estimated using the modified strip theory of DeLaurier with improvements by Han. Moreover, in-flight dynamic wing deformations are experimentally measured using an eight-camera real-time digital motion analysis system. For experiments, the reduced frequency is calculated to be approximately 0.51; and *Re* number is about 22,600. Numerical studies that analyze nonlinear deformations of a rigid rectangular plate-like wing are carried out at *Re* number of about 6,400 and reduced frequency of about 0.26. Numerical and experimental results indicate that flapping-wing dynamics is very complicated and is primarily dominated by the unsteady aerodynamic loads. Hence, a reverse design process is recommended using optimization of the time-varying aerodynamic loads with assumed time-varying wing geometries.