Università di Genova

Department of Civil, Environmental and Architectural Engineering
University of Genoa

NUMERICAL SIMULATION OF THE UNSTEADY AERODYNAMICS OF FLAPPING FLIGHT

Joel GUERRERO

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E Pluribus Unum

Abstract

The aim of this dissertation is to contribute to a better comprehension of the mechanism of flapping airfoils/wings propulsion and the associated unsteady aerodynamics, independently of their possible practical applications. We describe an accurate and stable numerical method to numerically solve the incompressible Navier-Stokes equations, which, used together with the overlapping grids method and to the numerical tools implemented, constitutes a very powerful tool to solve fluid dynamics problems with fixed and moving/deforming boundaries in two and three space dimensions. The two-dimensional results are presented for airfoils undergoing heaving and coupled heaving-and-pitching motion. The interest here is to determine the values of flapping frequency and flapping amplitude best suited for flapping flight, in terms of maximum propulsive efficiency and thrust production. We also study the influence of airfoil cambering and airfoil flexibility on the aerodynamic performance. Finally, three-dimensional rigid finite-span wings undergoing heaving, coupled heaving-and-pitching and root-flapping motion modes are investigated, with focus on the wake topology and aerodynamic performance, and their dependence on the flapping motion parameters. We also establish the best criteria for vortical structures identification and assess whether the assumption of two-dimensionality has some validity in three-dimensional cases.