MIDWEST MECHANICS SEMINAR

Large scale numerical experiments of unsteady aerodynamic flows and the role of laminar-turbulent transition

MONDAY APRIL 8TH, 10:30AM-11:20AM
RHPH 164

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Abstract

Fluid flows subject to time-dependent external forces or boundary conditions are ubiquitous in aeronautical applications. Whether one considers pitching wings, dynamic stall or the gust response of wind turbines, the flow is unsteady or non-autonomous. We investigate the influence of unsteadiness on the non-linear flow evolution, as well as on the linear response to small disturbances that determines their stability and the subsequent transition to turbulence. The simulations are performed with a high-order spectral-element method (SEM) with the domain discretized by up to several billion grid points. The capabilities of our SEM solvers are presented and two flow cases are studied in more detail. First, a small amplitude pitching wing where the laminar-turbulent interface drastically changes its cordwise location, and subsequently the dynamic stall of an airfoil undergoing a large pitchup motion.

We assess the potential of the optimally time-dependent (OTD) framework for transient linear stability analysis of flows with arbitrary time-dependence using a localized linear/non-linear implementation. This framework is first tried on oscillating plane Poiseuille flow to show the potential of the method and subsequently used to track the linear stability of laminar separation bubbles on unsteady wings. For the pitching case the global mode corresponding to an absolute local instability is identified at the rear of the separation bubble, causing its breakdown to turbulence.

The influence of low-amplitude free-stream disturbances on the onset of dynamic stall is also investigated and the onset of intermittent vortex shedding during the bubble bursting is documented. Here the Proper Orthogonal Decomposition framework is extended to include time dependence. This allows for the objective extraction of transient structures from data. Large structures shedding the bubble are identified as precursors of the detachment of the dynamic stall vortex.

Biography

Dan Henningson is Professor of Fluid Mechanics at KTH Royal Institute of Technology since 1999, where he also obtained his PhD in 1988. Earlier he held positions as Assistant Professor of Applied Mathematics at MIT and as Senior Researcher at the Aeronautical Research Institute of Sweden. At present he is also holding an Endowed Professor Chair at Instituto Tecnológico de Aeronáutica, Brazil, in Honor of Peter Wallenberg Sr. Professor Henningson has made contributions to the areas of large-scale numerical simulation of laminar-turbulent transition and its control, in particular so-called bypass transition in boundary layers under free stream turbulence, and more recently in the area of unsteady aerodynamics flows. His early theoretical work is summarized in the highly cited Springer monograph, Stability and Transition in Shear Flows, where the work on transient growth and non-normal effects in the laminar-turbulent transition process was highlighted. Professor Henningson has been instrumental in creating a number of excellent research environments, in particular as the founding Director of the Linné FLOW Center, the Swedish e-Science Research Center and the Swedish Aerospace Research Center. Professor Henningson is the recipient of the prestigious Humbolt Prize and a European Research Council Advanced Grant. He is also an American Physical Society and EUROMECH Fellow as well as a member of the Royal Swedish Academy of Engineering Sciences.

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