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Title

Dynamic stall models for post flutter analysis of an aeroelastic wing section

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Abstract

Aeroelastic phenomena, i.e. flutter, are a major concern for aircraft designers because of the dramatic consequences on the aircraft structure they can engender. Recent solar powered HALE (High Altitude Long Endurance) drones are designed with lightweight structures and very flexible high-aspect-ratio wings that are vulnerable to this phenomenon, as experienced by NASA's Helios project and more recently Airbus' Zephyr. Efforts must still be done to improve engineering tools combining, beam models, unsteady and nonlinear aerodynamics, and flight mechanics.
Kirsch et al [1] led to the development of a computational code (GEBTAero) for the simulation of an anisotropic composite flexible wing allowing to determine the flutter critical airspeed for different configurations using aeroelastic tailoring. The model is based on a geometrically exact beam theory coupled with a two-dimensional unsteady finite state aerodynamic model. To date, as this model does not consider non-linear unsteady aerodynamics, such as dynamic stall that occurs for an airfoil during pitching and plunging oscillations, limit cycle oscillations (LCOs) that are observed in the neighbourhood of the flutter in wind tunnel experiments [2] cannot be predicted.
The work presented in this communication aims to implement and to assess dynamic stall models that will be convenient for aeroelastic modelling of HALE drone wings with GEBTAero, the nonlinear effect of the dynamic stall changing drastically the way the wing moves in the airflow. Before implementing nonlinear aerodynamics in the full code, the first step is to employ a simplified 2D aeroelastic model to compare formulation, accuracy and robustness of different dynamic stall models considering low and high reduced frequency movements.
Using a typical 2D aeroelastic model of an airfoil that rotate around an axis thanks to a pitching spring and oscillate thanks to a plunge spring, combined to a dynamic stall model to compute aerodynamic forces and moments, the resulting nonlinear aeroelastic formulation is solved in the frequency domain to predict the flutter critical airspeed and in the temporal domain to exhibit the airfoil movement and limit cycle oscillations that could be observed. Dynamic stall models existing in the literature, Oye [3], Snel [4] or Beddoes-Leishmann [5] and its variation [6], were implemented and first assessed by comparison with experimental data and test cases available in [5] and [7], in term of aerodynamic coefficient prediction for an imposed pitch oscillation with different amplitude and reduced frequency (defined by the ratio between the fluid frequency and the solid motion frequency). Then, considering the aeroelastic formulation for an airfoil and defining some appropriate test cases in terms of flow velocity and reduced frequencies or test cases described in [7], the different models were evaluated by comparing LCOs prediction. In particular, results show that using Snell model, rather than Oye or Riso models, can lead to divergent pitch or plunge displacement more particularly for high

reduced frequency motion. The results also show the computation time is impacted by the different models and their complexity.

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