NUMERICAL VALIDATION OF ACTUATOR LINE METHOD FOR SUBCRITICAL FLUTTER PREDICTION

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ABSTRACT

With the purpose of reducing aviation emissions, scientific investigations push towards lightweight High Aspect Ratio (HAR) wings with increasing aerodynamic efficiency. These very flexible structures show nonlinear dynamics due to large deformations and/or stall effects which may cause supercritical or subcritical flutter response. The early-stage assessment of this phenomena in the design process is then crucial to avoid late redesign, production costs and delays. This paper investigates the capability of the Actuator Line Method (ALM) to reproduce subcritical flutter for a typical section. Solving the 2D Navier-Stokes equations by body forces distributed along a line, the ALM aerodynamics is coupled with plunge and pitch elastic equations [1] and used to predict flutter onset, post-flutter limit-cycle oscillations and bifurcation characteristics of a typical section. As a numerical benchmark, the results presented by Riso et al. in [2] will be replicated, matching structural properties and flow conditions. The comparison with the reference model is used to assess accuracy and limitations of the ALM computational technique. This study is the first step toward an experimental validation, aiming at establishing ALM as a tool for nonlinear aeroelastic analysis and design.

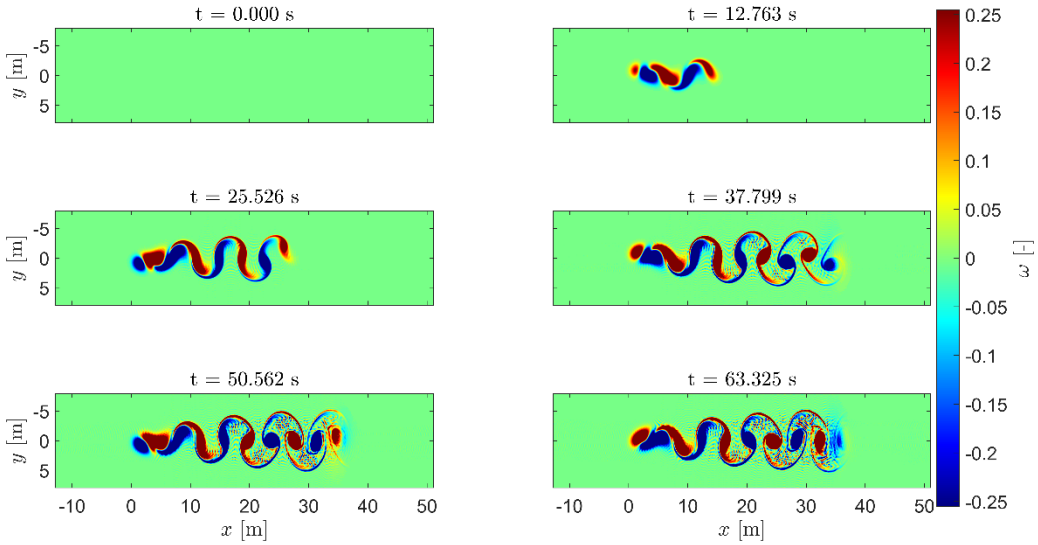

Figure 1. Vorticity snapshots at different time steps for a typical section model using plunge and pitch elastic equations coupled with ALM-based Navier-Stokes.

REFERENCES

[1] Alva, E., Kleine, V. G. and Cavalieri, A. V. G. *On the applicability of the actuator line method for unsteady aerodynamics*, 2025, arXiv preprint arXiv:2501.17395

[2] Riso, C., Cesnik, C. E. S. and Epureanu, B. I. *Bifurcation-Diagram-Free Postflutter Response Constraint for Design Optimization*. AIAA Journal 2023, https://doi.org/10.2514/1.J062012