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CFD Based Reduced Order Models for T-tail flutter

A. Attorni, L. Cavagna, G. Quaranta[†]
Dipartimento di Ingegneria Aerospaziale, Politecnico di Milano,
via La Masa 34, 20156 Milano, Italy. fax: +39-02-2399-8334

Abstract

This paper illustrates the application of Computational Fluid Dynamics (CFD) for the aeroelastic analysis of aircraft undergoing arbitrary free flight motion in transonic flight regime. In particular, the problem of T-tail flutter instability is adressed.

CFD is a consolidated technology for aerodynamics analysis today, and its use is becoming more and more common in aeroelasticity as well, typically applied to aircraft deformable models based on Component Mode Synthesis (CMS) from Finite Element Analysis (FEA) [1] or even from modal survey by Ground Vibration Testing (GVT) as in the case of the present work.

The key aspect of applying CFD to aeroelasticity is related to efficiency in terms of minimal computational cost, since aeroelastic computations, in the time domain, considerably add to the complexity of the fluid dynamics simulation.

The adoption of Reduced Order Models (ROM) for the generalized aerodynamic forces is useful to lower the computational costs required for flutter assessment. ROMs created by means of CFD codes, can be transformed into a state-space model which enables to perform aeroservoelastic analysis, modelling of actuators dynamics and assess the control laws directly in the time-domain using techniques typical of modern control. The adoption of a reduced model guarantess computational savings especially if several analyses are required to investigate the sensivity of the response of the aeroservoelastic system when gains, laws and actuators are modified.

Keeping in mind to minimize the number of expensive CFD runs, the following points are required to assess flutter instability:

- trim algorithm for the determination of flight mechanics parameters required for a prescribed steady flight maneuver (angle of attack, controls, angular rates);
- ROM creation and its state-space representation for fast flutter tracking;
- non-linear direct coupled dynamic simulation to determine the stability of the response of the system starting from the equilibrated condition and confirm the results predicted by the linearized analysis (see Figure 1).

The methods presented here are applied to a real-life case: Piaggio P-180 aircraft featuring a T-tail, a non conventional three surfaces architecture with blended nacelles in the main wing and pushing propellers (see Figure 2). The complexity of the architecture under consideration is a good test-bench to show the present method is naturally ready to investigate further interesting phenomena like the transonic condition of the tail empennages, the effect of propellers, the interference of the wake of the canard on the wing and viscosity effects; everything can be included in the developed model to enhance its accuracy. Even though the tail is not in transonic condition for the cases investigated so far, the importance of more complex models on this test-case is highlighted.

[†]Corresponding author, mail: *quaranta@aero.polimi.it*, phone: +39-02-2399-8405, fax: +39-02-2399-8334.

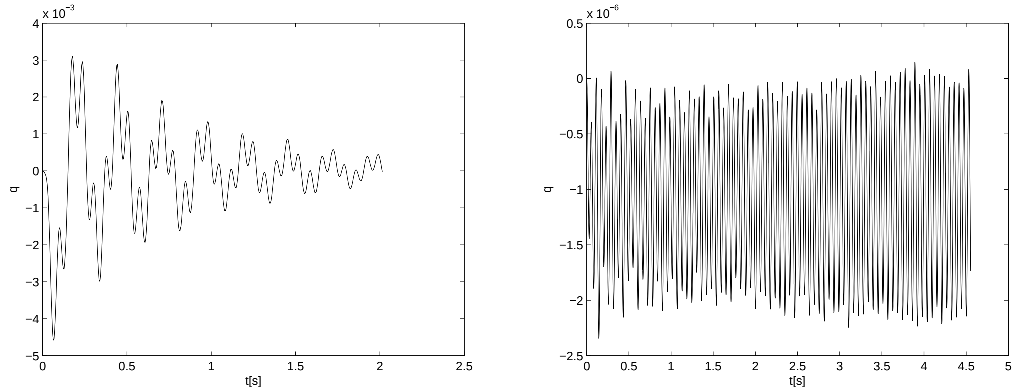

Figure 1: Damped and self-substained responses

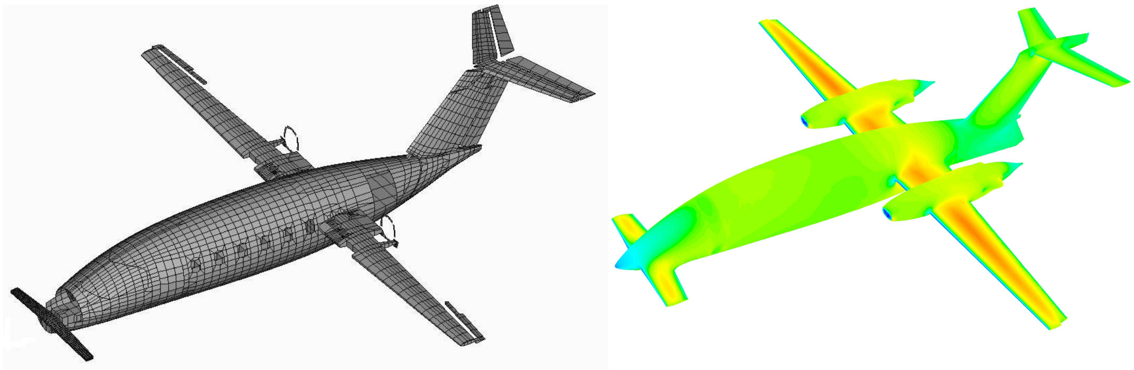

Figure 2: Structural and aerodynamic model

The present work shows how the adoption of CFD techniques improves the prediction for flutter in T-tails since the ROM is influenced by the reference load condition. The steady pressure load on the tails is a well-known key factor in T-tail flutter stability as reported in [2].

One of the main goals of the present work is to show how robustness of results and ease of use can be achieved with limited efforts and to prove the application of aeroelastic analysis on a full aircraft configuration can be carried out routinely. In this particular case, the whole aircraft is indeed required in order to determine the correct trimmed condition and the aerodynamic condition the tail is subjected, in particular its steady pressure-load distribution in flight.

References

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[2] W. Jennings and M. Berry, "Effect of Stabilizer Dihedral and Static Lift on T-Tail Flutter," *Journal of Aircraft*, vol. 14, pp. 364–367, April 1977.