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Numerical simulation of the unsteady flowfield in complete propulsion systems

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Abstract. A non-linear numerical simulation technique for predicting the unsteady performances of an air-breathing engine is developed. The study focuses on the simulation of integrated propulsion systems, where a closer coupling is needed between the airframe and the engine dynamics. In fact, the solution of the fully unsteady flow governing equations, rather than a lumped volume gas dynamics discretization, is essential for modeling the coupling between aero-servoelastic modes and engine dynamics in highly integrated propulsion systems. This consideration holds for any propulsion system when a full separation between the fluid dynamic time-scale and engine transient cannot be appreciated, as in the case of flow instabilities (e.g., rotating stall, surge, inlet unstart), or in case of sudden external perturbations (e.g., gas ingestion). Simulations of the coupling between external and internal flow are performed. The flow around the nacelle and inside the engine ducts (i.e., air intakes, nozzles) is solved by CFD computations, whereas the flow evolution through compressor and turbine bladings is simulated by actuator disks. Shaft work balance and rotor dynamics are deduced from the estimated torque on each turbine/compressor blade row.

Keywords: propulsion system simulation; gas-turbines; compressible flows; CFD

1. Introduction

In high-performance propulsion systems, the actual working conditions are very close to critical modes as compressor stall or inlet unstart. Future vehicles proposed for supersonic commercial flights are also characterized by a long, slim body with pronounce aero-servoelastic modes (Kopasakis *et al*. 2010). In general, the modern engine concepts are moving toward highly integrated, multi-architecture propulsion systems which include more than one engine type in the same system (e.g., over-under TBCC engines, McDaniel 2012), or have a variable thermodynamic cycle (Fernandez-Villace and Paniagua 2013, Zheng *et al.* 2017). In many cases, engine-airframe integration effects performances and the fully unsteady treatment of the fluid dynamics inside and outside the engine must be taken into account for a reliable simulation of the propulsion system dynamics and for control purpose (see Benek *et al*. 1998, Litt *et al*. 2015).

Mathematical modelling and system simulation are generally used to resolve propulsion system

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