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[Extended Abstract]

Complete Prediction of Modern Turbofan Tonal Noise at Transonic Regime

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Introduction

Modern aircraft engines are designed as compact as possible and are characterized by short asymmetric air inlet ducts and heterogeneous Outlet Guide Vanes (OGV). The heterogeneity of the OGV has already been studied by Bonneau et al. [1] and Roger et al. [2] who explained the invalidity of the classical Tyler and Sofrin's rule [3] for such geometries. Because of the asymmetric air inlet, the flow in modern engines is also circumferentially non-uniform (or distorted) and first studies have shown that the resulting noise is impacted [4]. In particular, it has been shown that the inlet distortion is responsible for new sources on fan blades, and for a modification of the fan-OGV interaction mechanism which is classically supposed to be dominant. This study highlighted the fact that everything is coupled in such configurations and that the noise cannot be evaluated by considering the inlet/fan and the fan/OGV problems independently like it is usually done. Accordingly, a whole 360-degree fan stage is considered here, including an asymmetric air inlet, a fan, an heterogeneous OGV row and homogeneous Inlet Guide Vanes (IGV). A simulation of the Unsteady Reynolds-Averaged Navier-Stokes (URANS) equations has been performed. It is similar to the one done in [4], but with a much finer grid to allow direct acoustic analysis (570 millions of cells instead of 70 millions), and in a transonic regime to estimate the contribution of the shock noise mechanism. All fan tone sources are therefore included (including the usually neglected ones, like distortion/fan and fan/IGV interactions) and the purpose of the present paper is to estimate their relative contribution and their possible interactions.

Presentation of the simulation

The simulation has already been done using ONERA's solver *elsA* [5] based on a cell-centered finite volume approach on a structured multi-block grid. Wilcox $k-\omega$ two-equation model is used to determine the turbulent quantities. Spatial discretization is done with Roe's scheme (third order accuracy) and the implicit backward Euler scheme with Dual Time Step (DTS) sub-iteration algorithm is used for the temporal one (second order accuracy). One blade passage is described by 200 time steps, leading to a total of 3600 time steps per rotation (18 blades). A classical injection boundary condition (total pressure, total enthalpy and flow direction) is used at the inlet. A massflow condition is imposed at the exit of the primary flux (downstream of the IGV) while a radial equilibrium with a valve law is used at the exit of the secondary flux (downstream of the OGV). Sliding non-conformal interfaces are used between the rotating parts (fan) and the fixed parts (air inlet, IGV and OGV). The whole mesh is composed of 570 millions of cells and has been done in order to have at least 20 points per wavelength at the 2BPF (necessary to propagate acoustic waves correctly). A view of the Q-criterion colored by the vorticity modulus is given in Fig. 1 to have a global idea of the computational domain.

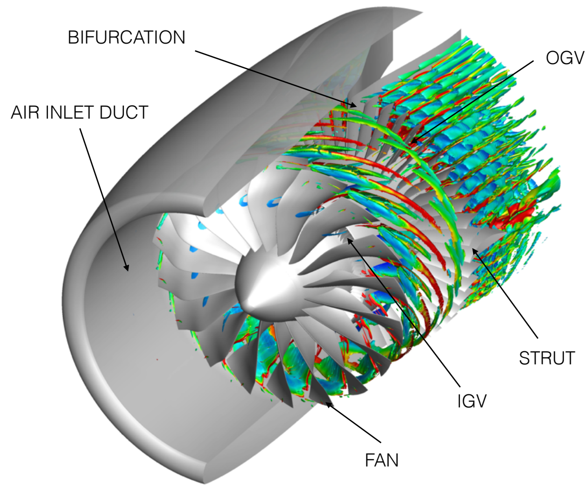

Figure 1. Isosurface of the Q-criterion colored by the vorticity modulus

References

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