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A LINEARIZED EULER SOLVER FOR COMPUTATION OF TONAL NOISE RADIATION FROM LINED TURBOFAN NOZZLES

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ABSTRACT

This paper describes an aeroacoustic model developed recently for predicting sound propagation and radiation through acoustically treated turbofan nozzles and the jets issuing from them. The model is based on the direct solution of the linearized Euler equations in frequency domain. The base (mean) flow and the geometry are both assumed axisymmetric. Then, for a single spinning azimuthal mode order the acoustic field is also axisymmetric. This allows analytical treatment of the azimuthal derivatives in the linearized Euler equations as well as the boundary conditions, reducing the problem to practically two dimensions, axial and radial coordinates. The standard impedance condition is used on acoustically treated portions of the duct walls. All the equations including the boundary conditions are discretized using high-order finite differences. The resulting large linear system of equations is solved in parallel by employing a state-of-the-art sparse matrix solver. Example calculations are presented for realistic engine geometries at realistic operating conditions.

INTRODUCTION

Engine fan noise remains as an important contributor to the overall noise emitted from large body aircraft. This is particularly the case at take-off. Although significant effort has been spent on prediction and suppression of inlet noise radiated forward, such activity for the fan exhaust noise has remained limited. Having this as one of the motivating points, three years ago the European Commission sponsored research project TURNEX (Turbomachinery Noise Radiating from the Engine Exhaust) was initiated. Within the scope of this project, a direct, frequency domain, linearized Euler solver, named FLESTURN, has been developed.

Fan exhaust noise prediction is not straightforward as the sound waves propagate through highly nonuniform nozzle and jet flowfields. Convective instabilities exist in the jets, from which time domain numerical methods suffer, as the linearized Euler equations also support these instabilities. However, Agarwal et al [1] demonstrated that the numerical difficulties associated with the temporal growth of these instabilities are filtered out, if the linearized Euler equations are formulated in the frequency domain. Hence, a frequency domain approach has been used in FLESTURN.

In the present aeroacoustic model, the geometry is assumed axisymmetric, and the acoustic field is composed of a single spinning mode order *m*, reducing the equations effectively to the so called 2.5 dimensions; that is, to the axial and radial coordinates only. Acoustic sources are introduced to the domain from the duct inlet, and the outgoing waves are absorbed through the perfectly matched layer (PML) equations [2]. On acoustically treated walls, the standard Myer's impedance boundary condition [3] is applied. All the equations are transformed to body-fitted curvilinear coordinates and finite-differenced to high order accuracy, yielding a large, linear system of algebraic equations. This system is solved using the public domain sparse matrix solver MUMPS [4]. Far-field predictions are carried out using an open Kirchhoff surface enclosing the jet and shear layer.

The mean flow required by FLESTURN is interpolated to the acoustic mesh from the CFD mesh using an external code. There is no restriction on the form of the mean base flow. It can be viscous or inviscid, as the mean flow gradients are totally retained in FLESTURN. For the present analysis, the Reynolds Averaged Navier-Stokes (RANS) solver of the Fluent software has been used.

RESULTS

An example result is presented here in this abstract. Fig. 1 shows a generic short nacelle engine geometry and the computational acoustic mesh employed. Fig. 2 presents the mean flow field obtained from a RANS calculation at the engine approach condition. The open Kirchhoff surface employed for far-field predictions is also shown in this figure. Fig. 3 illustrates the acoustic field driven by the plane wave mode at 866 Hz. It is clear that quite a smooth acoustic field has been obtained.

There will be additional results and discussion in the full paper.

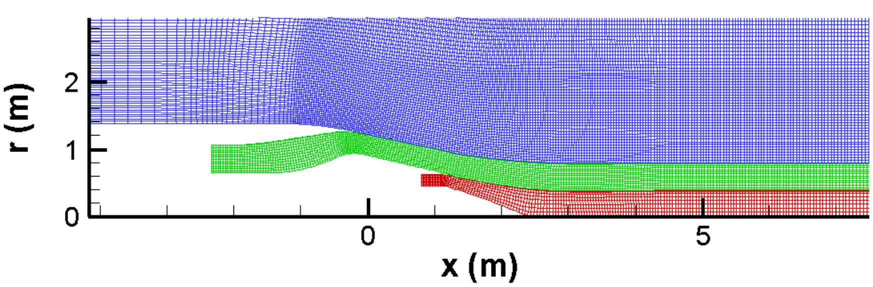

Fig 1: Close-up view of approach acoustic mesh. Every 4th grid line is shown.

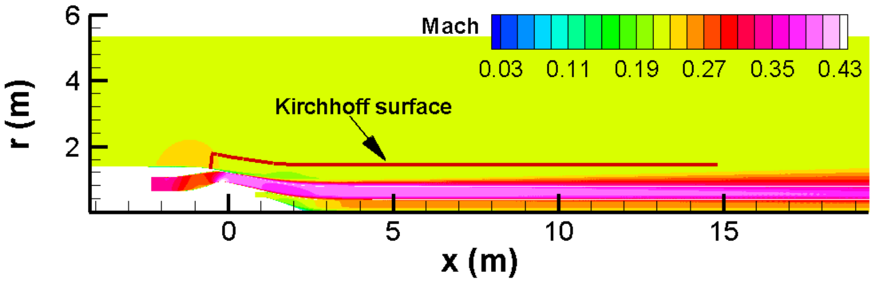

Fig 2: Approach mean flow and Kirchhoff surface.

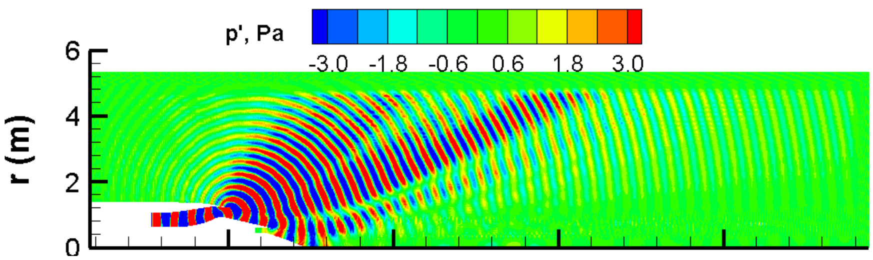

Fig 3: Acoustic field of (0,1) mode at approach and 866 Hz, with rigid walls.

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