Unified Solver for Fluid Dynamics and Aeroacoustics in Isentropic Gas Flows

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ABSTRACT

The propagation of acoustic waves is a physical phenomenon which can only be described taking into account the compressibility of the medium. The high computational cost of the compressible Navier-Stokes equations, as well as its poor performance in the low Mach regime, has led to the necessity for more affordable numerical models for Computational Aeroacoustics. Moreover, for subsonic flows without thermal coupling both flow dynamics and wave propagation can be considered isentropic. Therefore, it is reasonable to consider a formulation which is capable of capturing the acoustics within a Computational Fluid Dynamics (CFD) calculation in a single run, without having to segregate both flow and acoustic scales like in acoustic analogies [1]. Under these assumptions density and pressure fluctuations are directly proportional, for which a two field velocity-pressure compressible formulation that can be derived as an extension of an incompressible solver. On the other hand, the resulting system will be better conditioned than the homologous incompressible one due to the effect of the new pressure terms in a similar way to the artificial compressibility method [2].

Like in all compressible formulations the prescription of boundary conditions will have to deal with the backscattering of acoustic waves. In this sense, a separated imposition of boundary conditions for flow and acoustic scales which allows the evacuation of waves through Dirichlet boundaries without using any tailored damping model will be presented [3], [4].

REFERENCES

[1] LIGHTHILL, M.J. 1952. On sound generated aerodynamically I. General theory. Proceedings of the Royal Society of London. Series A. Mathematical and Physical Sciences, 211(1107):564–587.

[2] CHORIN, A.J. 1967. A numerical method for solving incompressible viscous flow problems. Journal of computational physics, 2(1):12–26.

[3] ESPINOZA, H., CODINA, R. and BADIA, S. 2014. A Sommerfeld non-reflecting boundary condition for the wave equation in mixed form. Computer Methods in Applied Mechanics and Engineering, 276:122–148.

[4] CODINA, R. and BAIGES, J. 2015. Weak imposition of essential boundary conditions in the finite element approximation of elliptic problems with non-matching meshes. International Journal for Numerical Methods in Engineering, 104(7):624–654.