# Numerical approach for aeroacoustic problems

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Propagation of acoustic disturbances in non-uniform flows is a subject of great interest in many practical problems, particularly in transport engineering with automotive exhaust systems, aeronautical turbofan engine inlet ducts, etc. The understanding of this phenomenon is a central feature for the prediction of noise and for designing components that efficiently attenuate sound. The Linearized Euler Equations (LEEs) form the basic starting point for the majority of the currently used computational aero-acoustic (CAA) models. Under a few simplifying assumptions, one can be satisfied with the full-potential formulation. The full potential formulation is obtained from the LEE by assuming both flow and disturbances irrotationality. Thus, it constitutes a specific case of the general LEE.

We propose in this intervention the numerical development of another operator on which we have been working for two decades: Galbrun's equation.

Galbrun’s equation can be viewed as a LEE alternative which describes exactly the same physical phenomena. This equation is derived from an Eulerian-Lagrangian description. This description consists in considering Lagrangian perturbation of physical quantities associated to fluid particles expressed in terms of geometrical Eulerian variables. Galbrun’s equation constitutes a second-order linear partial differential equation written only in terms of the displacement perturbation (even in non-homentropic cases).

However, its direct numerical treatment by FEM has been source of difficulties due to the well-known locking phenomenon which usually occurs with a purely displacement based formulation. A mixed pressure-displacement FEM formulation has been previously proposed to avoid a spurious solutions phenomenon. This mixed approach is general and easy to implement in a FEM code and has been tested successfully for the harmonic/time-domain and bounded/unbounded space domain.

Through a number of examples, we show its accuracy and effectiveness.